OPERATING AND SERVICE MANUAL

(HP PART NO. 00651-90003)

MODEL 651A
TEST OSCILLATOR

SERIALS PREFIXED: 547-

Appendix C, Manual Backdating Changes, adapts this manual to serial numbers below 547-01976, and serial prefixes 416-, 427-, and 434-.

P. O. Box 301, Loveland, Colorado, 80537 U. S. A.

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SECTION I GENERAL INFORMATION

SECTION II INSTALLATION

SECTION III OPERATING INFORMATION

SECTION IV PRINCIPLES OF OPERATION

SECTION V MAINTENANCE

SECTION VI REPLACEABLE PARTS

MANUAL BACKDATING CHANGES

MODEL 651A

TEST OSCILLATOR

Manual Serial Prefixed: 547-
Stock No. 00651-90003

This manual backdating sheet makes this manual applicable to earlier instruments. Instrument-component values that differ from those in the manual, yet are not listed in the backdating sheet, should be replaced using the part number given in the manual.

Instrument Serial Prefix	Make Manual Changes	Instrument Serial Prefix	Make Manual Changes
416 and 427	1, 2		
434	2		
547-01976 and below	3		

CHANGE #1 Tables 6-1 and 6-2:
Change Stock No. for A3 from 00651-63402 to Stock No. 00651-63401.

CHANGE #2 Figure 5-9, Tables 6-1 and 6-2:
Delete A1R29, Stock No. 0766-0029.

CHANGE #3 Tables 6-1 and 6-2:
Change Stock No. for A1Q8 and A2Q7 from 1854-0044 to 1854-0218.

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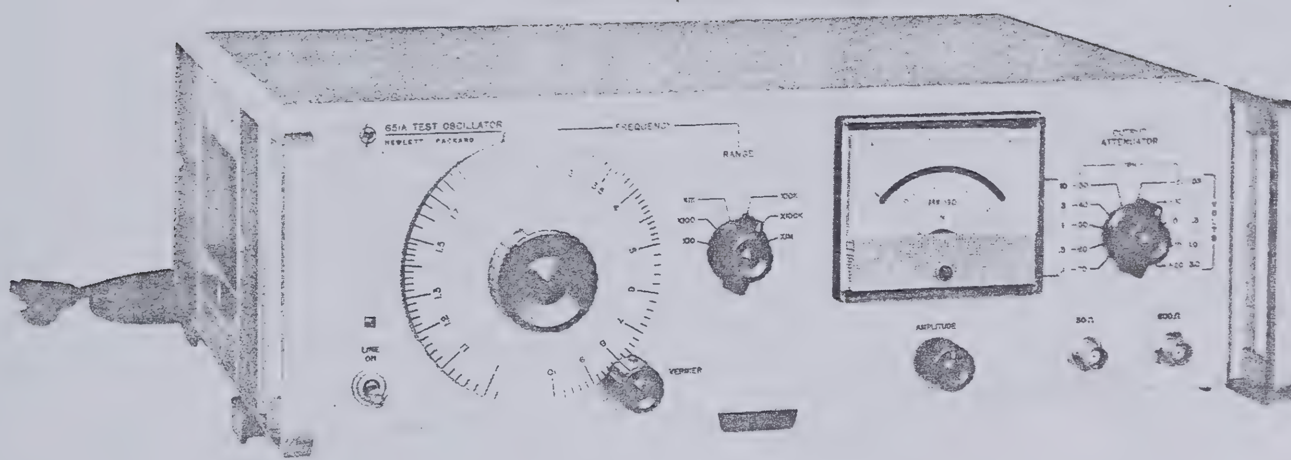


Figure 1-1. Model 651A Test Oscillator

Table 1-1. Specifications

Frequency Range: 10 cps to 10 mc. 6 bands, dial calibration: 1 to 10.

Frequency Stability: Typically 10 ppm/minute, after 2 hour warmup.

Frequency Response:

Flat within: ±2% 100 cps to 1 mc.
±3% 10 cps to 100 cps.
±4% 1 mc to 10 mc. *

Dial Accuracy: (Including warm-up drift and ±10% line variations).
±2%, 100 cps to 1 mc.
±3%, 10 cps to 100 cps, 1 mc to 10 mc.

Output: 200 mw (3.16 v into 50 ohms); 16 mw (3.16 v into 600 ohms) 6.32 v open circuit.

Attenuator:

Range: 90 db in 10 db steps.

Overall Accuracy: ±0.1 db, .3 v thru 3 v ranges
±0.2 db, .1 v range

Amplitude Control: 20 db range (nominal).

* This specification applies only at 50 or 75 ohm output. The response above 1 mc at the 600 ohm output is affected by capacitive loads.

Output Monitor: Voltmeter monitors level at input of attenuator in volts or db. Top scale calibrated in volts. Bottom scale calibrated in db.

Accuracy: ±2% at full scale.

Flatness: ±1% at full scale, 20 cps to 4 mc.
±2% at full scale, 10 cps to 20 cps, 4 mc to 10 mc

Distortion: Less than 1% 10 cps to 5 mc, approximately 2% at 10 mc.

Hum and Noise: Less than .05% of maximum rated output.

Temperature Range: 0°C to +50°C.

Weight:

Net: 17 lbs. (7,65 kg)

Shipping: 22 lbs. (9.90 kg).

Power: 115 v/230 v ±10%, 20 watts, 50 to 1000 cps.

Dimensions: 5-7/32" high, 16-3/4" wide, 13-1/4" deep (132,6 x 425 x 336 mm).

SECTION I
GENERAL INFORMATION

1-1. DESCRIPTION.

1-2. The Hewlett-Packard Model 651A Test Oscillator is a wide range capacitance-tuned oscillator covering a frequency range from 10 cps to 10 Mc. The oscillator has a stable sine-wave output signal that is adjustable from 10 microvolts to 3.16 volts into 50 or 600 ohms. The Model 651A Test Oscillator is shown in Figure 1-1 and the specifications are given in Table 1-1. This manual is written for the standard Model 651A Test Oscillator. Refer to paragraph 1-7 for differences between the standard instrument and Options 01 and 02.

1-3. Two output impedances are provided at front panel output connectors. The 600-ohm connector provides an output with an impedance that is compatible with transmission lines and many distribution systems. The 50-ohm connector provides an output where a low-source impedance is desired.

1-4. The Model 651A Test Oscillator output voltage is constantly monitored at the input to the attenuator by an internal voltmeter. This voltmeter has two scales for RMS voltage readings and a dbm scale referenced to 1 milliwatt into 50 ohms. The OUTPUT ATTENUATOR, in conjunction with the AMPLITUDE control and voltmeter, provides a monitored output signal of desired level when matched into 50- or 600-ohm load.

1-5. ACCESSORIES AVAILABLE.

1-6. Table 1-2 contains a list of the accessories which will increase the usefulness of your Test Oscillator.

1-7. OPTIONS AVAILABLE.

1-8. OPTION 01.

1-9. Option 01 is a standard ⓗ Model 651A Test Oscillator with a 600 ohm dbm scale output meter. The front panel OUTPUT ATTENUATOR dbm markings have been changed to correspond with the signal level at the 600 Ω output connector (-80 to +10 DBM).

1-10. OPTION 02.

1-11. Option 02 is a standard ⓗ Model 651A Test Oscillator with a 75 ohm dbm scale output meter. The front panel output connector markings have been

Table 1-2. Accessories Available

Model No.	Use	Features
ⓗ 11004A	Line Matching Transformer provides balanced 135- or 600-ohm input to 600-ohm unbalanced output for measurements on balanced lines.	Terminating Resistance: 600 or 10 K ohms Frequency Range: 5 kc to 600 kc Power Handling Capacity: +22 dbm (10 v into 600 ohms)
ⓗ 11005A	Line Bridging Transformer provides balanced 600-ohm input to unbalanced 600-ohm output for balanced-line measurements.	Terminating Resistance: 600 or 10 K ohms Frequency Range: 20 cps to 45 kc Power Handling Capacity: +15 dbm (4.5 v into 600 ohms)
ⓗ 10110A	Adapter to convert Model 651A BNC output connectors to binding post connectors.	BNC Male to Binding Post Adapter
ⓗ 11000A	Cable Assembly used in conjunction with 10110A Adapter.	Dual Banana Plugs terminate a section of 50-ohm cable
ⓗ 11001A	Cable Assembly used to convert from BNC connector to a banana plug connector	A section of 50-ohm cable terminated on one end by a UG-88C/U BNC connector and a dual banana plug on the other.
ⓗ 11048B	Feedthrough Termination used to insure instrument is operating into rated impedance in the event the instrument is connected to a device with an impedance greater than 50 ohms.	Terminating Resistance: 50 ohms ±0.25% Connections: BNC male on one end and BNC female on other end

changed to correspond with the 75 ohm and 600 ohm output impedance levels.

1-12. INSTRUMENT IDENTIFICATION.

1-13. Hewlett-Packard uses a two-section eight-digit serial number (000-00000). If the first three digits of the serial number on your instrument do not agree with those on the title page of this manual, change sheets supplied with the manual will define differences between your instrument and the Model 651A described in this manual.

1-14. If an E or G prefixes the serial number, the instrument was manufactured in Europe (E for England, G for Germany).

SECTION II
INSTALLATION

2-1. INSPECTION.

2-2. This instrument was carefully inspected both mechanically and electrically before shipment. It should be physically free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit. Also check for supplied accessories, and test the electrical performance of the instrument using the procedure outlined in Paragraph 5-3. If there is damage or deficiency, see the warranty on the inside front cover of this manual.

2-3. POWER REQUIREMENTS.

2-4. The Model 651A will operate from either 115 or 230 vac, 50 - 1000 cps. The instrument can be easily converted from 115 to 230 volt operation by changing the position of the slide switch, located on rear panel, so that the designation appearing on the switch matches the nominal voltage of the power source. A 0.25 ampere, slow-blow fuse is used for 115- and 230-volt operation.

2-5. THREE-CONDUCTOR POWER CABLE.

2-6. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. All Hewlett-Packard instruments are equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

2-7. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

2-8. INSTALLATION.

2-9. The ⓗⓟ Model 651A is fully transistorized; therefore no special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds 55°C (140°F).

2-10. RACK/BENCH INSTALLATION.

2-11. The Model 651A is initially shipped as a bench-type instrument (unless ordered specifically as a rack type) with plastic feet and a tilt stand in place. Conversion to a rack-mounted instrument can be accomplished by using the rack mounting kit and instructions furnished with your instrument.

2-12. REPACKAGING FOR SHIPMENT.

2-13. The following is a general guide for repacking for shipment. If you have any questions, contact your local ⓗⓟ Sales and Service Office (See Appendix B for office locations).

NOTE

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach to the instrument a tag identifying the owner and indicate the service or repair to be accomplished; include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number, serial number and serial number prefix.

a. Place instrument in original container if available. If original container is not available, it can be purchased from your nearest ⓗⓟ Sales and Service Office.

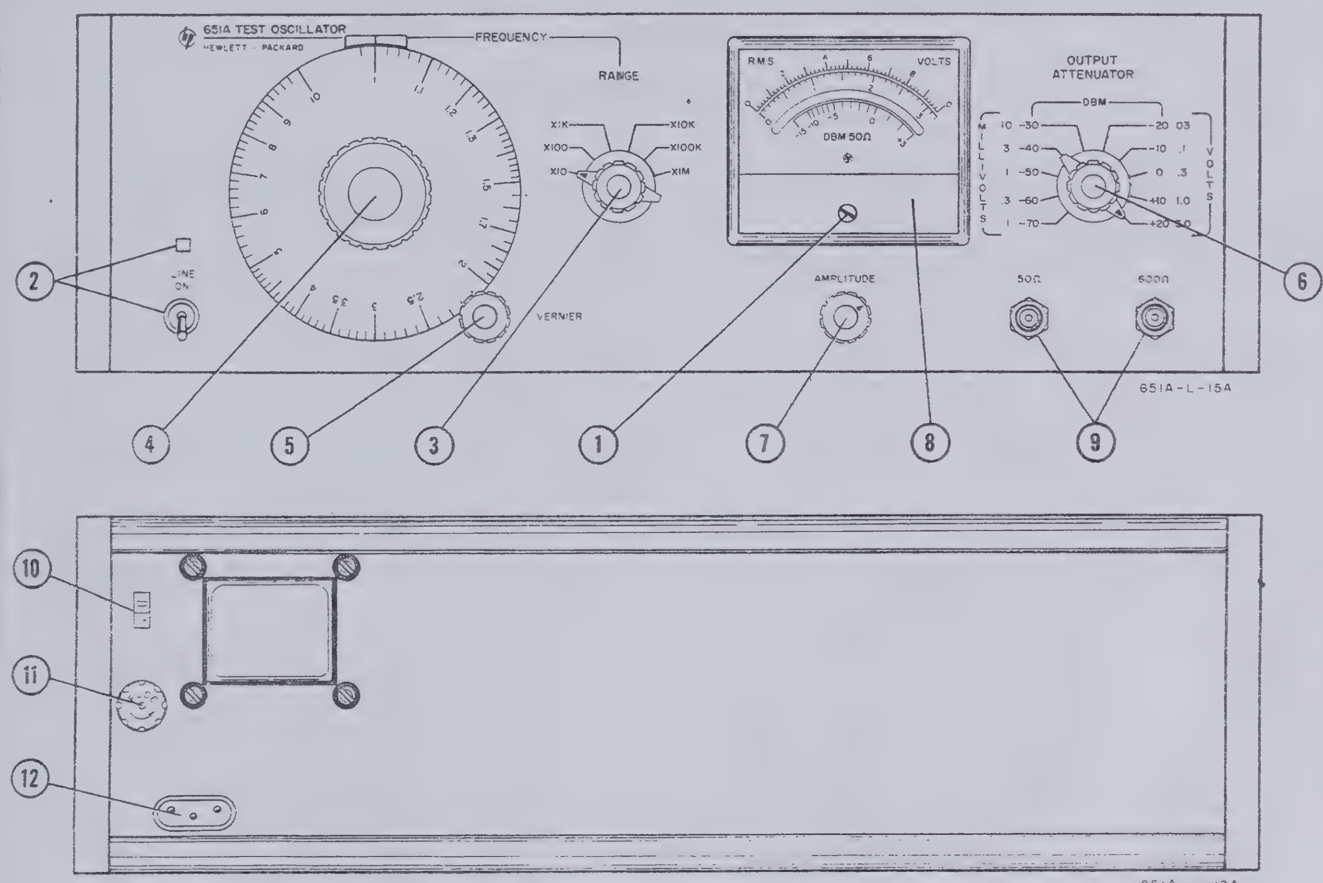
If original container is not used,

b. Wrap instrument in heavy paper or plastic before placing in an inner container.

c. Use plenty of packing material around all sides of instrument and protect panel faces with cardboard strips.

d. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.

e. Mark shipping container with "Delicate Instrument," "Fragile" etc.



1. MECHANICAL ZERO ADJUST: This adjustment mechanically zero-sets the meter prior to turning on Oscillator.
2. LINE-ON: This switch turns the instrument power on. Pilot lamp glows when Oscillator power is ON.
3. FREQUENCY RANGE: This switch selects one of six frequency ranges.
4. FREQUENCY DIAL: This dial is used to vary the output frequency within the band selected by the FREQUENCY RANGE switch. The dial is accurately calibrated from 1 through 10 with a 5% overlap at each end of the dial. The dial reading multiplied by the FREQUENCY RANGE switch setting is the instrument output frequency.
5. VERNIER: This control provides a fine frequency adjustment on the FREQUENCY dial.
6. OUTPUT ATTENUATOR: This ten-position switch is the output attenuator which is used to attenuate the output signal in 10 db steps to a maximum attenuation of 90 db. The instrument has an output impedance of 50 and 600 ohms.
7. AMPLITUDE: This control provides an output level adjustment which is continuously variable over a 20 db range between the 10 db steps of the OUTPUT ATTENUATOR switch.
8. OUTPUT MONITOR: This meter continuously monitors the Test Oscillator signal and indicates the input level to the OUTPUT ATTENUATOR in rms volts and dbm. The accuracy of the output monitor is ±2% of full-scale reading.
9. OUTPUT CONNECTORS: The 50 Ω and 600 Ω connectors (75 Ω and 600 Ω on Option 02) provide the output signal, selected by FREQUENCY RANGE switch and dial, at a level determined by the AMPLITUDE control and OUTPUT ATTENUATOR.

   NOTE

   The 50 Ω and 600 Ω output connectors can be used simultaneously by sacrificing output meter accuracy and taking a reduction in signal level available at the 600 Ω connector which will be approximately one half of the signal level available at the 50 Ω connector.
10. LINE VOLTAGE: This two-position slide switch sets the instrument to operate from a 115- or 230-volt ac power source. The voltage selected appears on the switch.
11. FUSE: This fuseholder contains a 0.4 ampere slow-blow fuse for 115- and 230-volt operation.
12. POWER INPUT: This three-prong connector is used to connect primary ac power to the Test Oscillator through the power cord furnished with your instrument.

Figure 3-1. Front and Rear Panel Description

SECTION III
OPERATION

3-1. INTRODUCTION.

3-2. The Model 651A Test Oscillator generates a stable sine-wave output which is available at two output impedance levels of 50 and 600 ohms. The output signal frequency can be varied from 10 cps to 10 Mc by the six-position FREQUENCY RANGE switch, the FREQUENCY dial and VERNIER control. The output power level is determined by the AMPLITUDE control and OUTPUT ATTENUATOR and can be varied from 10 microvolts to 3.16 volts into 50- or 600-ohm loads. The voltmeter located on the front panel monitors signal level at the input to the OUTPUT ATTENUATOR. Two voltage scales indicate voltage levels provided at the 50-ohm and 600-ohm output connectors. The third scale indicates the power level in dbm, referenced to 1 milliwatt into 50 ohms, at the 50-ohm output connector.

NOTE

The output meter may have an offset (small up-scale reading) when the instrument is turned ON and the AMPLITUDE control is turned fully CCW. This offset does not affect meter tracking above 1/10 scale.

3-3. CONTROLS AND INDICATORS.

3-4. Figure 3-1 describes the function of all front and rear panel controls, connectors, and indicators. The description of each component is keyed to a drawing which is included within the figure.

3-5. ADJUSTMENT OF MECHANICAL ZERO.

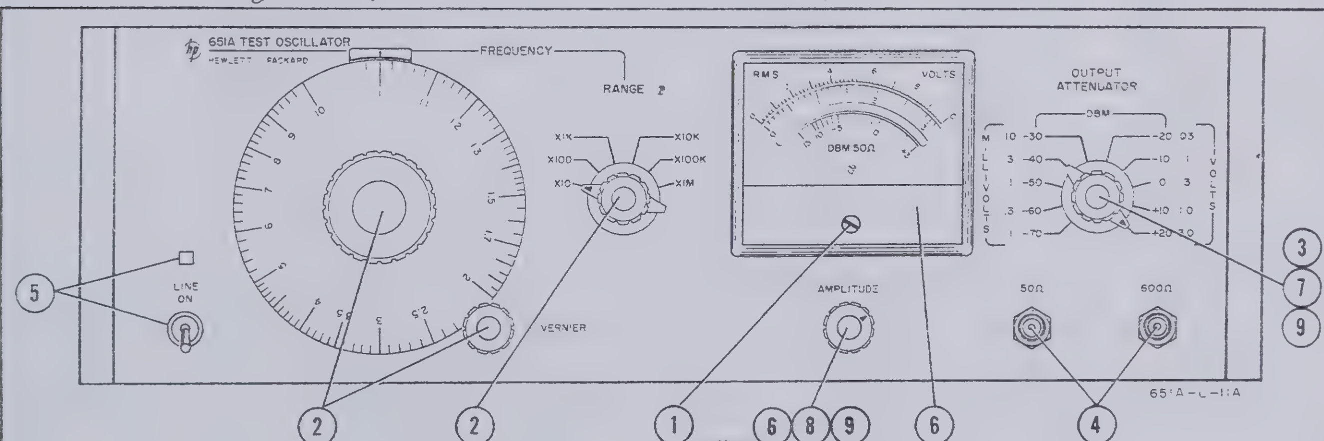
3-6. The procedure for adjustment of mechanical zero is given in Section V.

3-7. OPERATING INSTRUCTIONS.

3-8. Figure 3-2 contains operating procedures keyed to a drawing included in the figure. Refer to Figure 3-1 for the function of each control.

3-9. OUTPUT IMPEDANCE.

3-10. Refer to Paragraph 4-21 for changing the level of output impedance available at the 600-ohm output connector.



1. Zero-set meter prior to turning instrument on. Refer to Section V for Mechanical Zero adjustment procedure.
2. Set FREQUENCY RANGE switch and FREQUENCY dial to desired output frequency. Use VERNIER control for fine frequency adjustments.
3. Set OUTPUT ATTENUATOR switch to desired voltage range.
4. Connect load to output connector marked with impedance which matches the impedance of the load.
5. Place LINE switch ON; lamp glows.
6. Set AMPLITUDE control for desired output voltage by observing voltage scale on output monitor corresponding to selected voltage range.
7. Set OUTPUT ATTENUATOR for desired attenuation in 10 db steps.
8. Use AMPLITUDE control to obtain attenuation levels in dbm increments for each OUTPUT ATTENUATOR setting. A continuously variable 20 dbm range is available between 10 dbm steps.

   NOTE

   DBM Scale on meter accurate at 50-ohm output only. Refer to Paragraph 4-18 when using loads other than 50 ohms.

9. Set AMPLITUDE control for one-half scale reading when operating Test Oscillator into short circuit load. Set OUTPUT ATTENUATOR to +20 dbm position if 60 milliamperes of short circuit current are required. Reducing the amplitude of the output signal limits the current through the short circuit load.

Figure 3-2. Operating Instructions

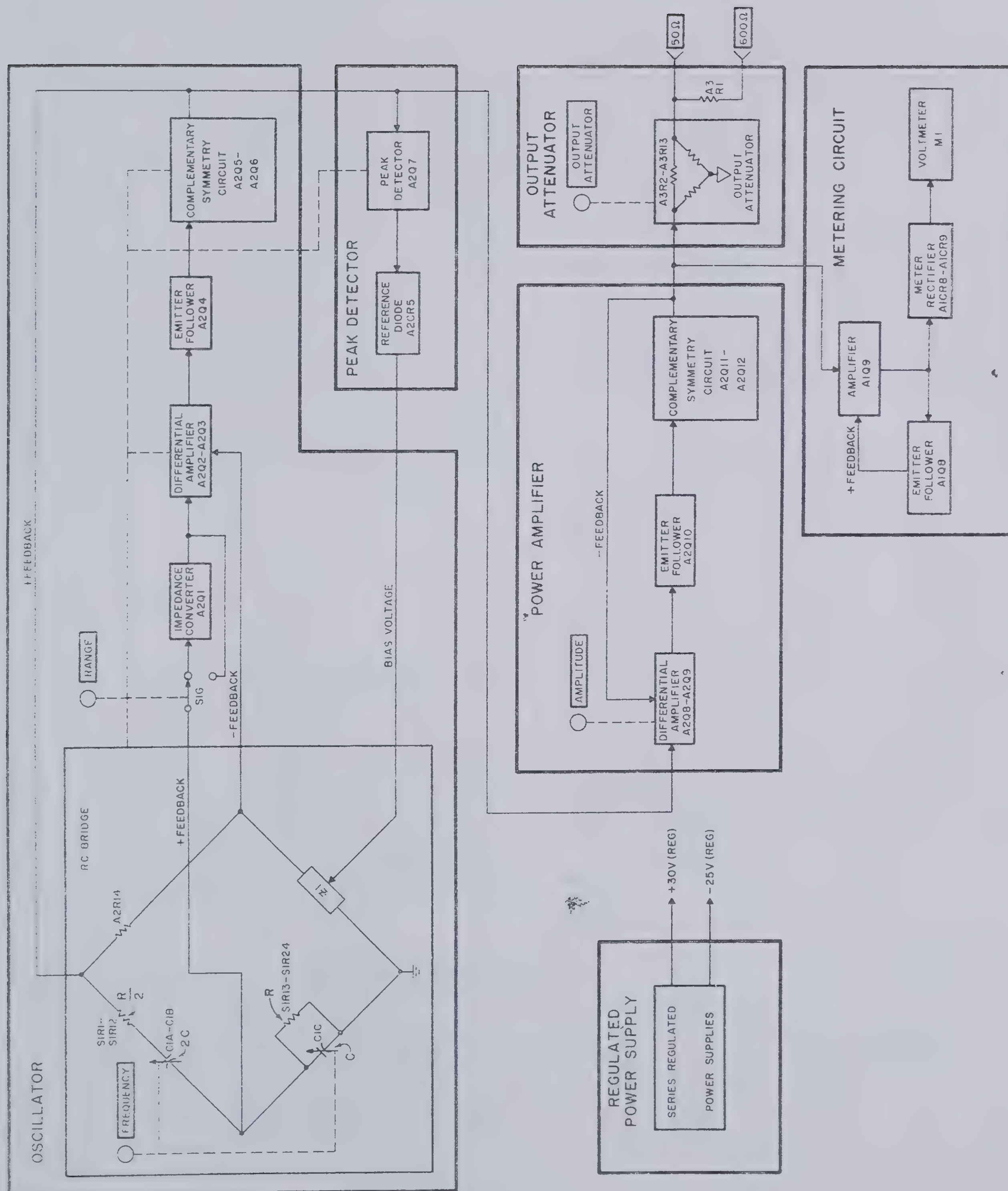


Figure 4-1. Model 651A Block Diagram

SECTION IV
PRINCIPLES OF OPERATION

4-1. OVERALL DESCRIPTION.

4-2. The Model 651A Test Oscillator includes an oscillator, power amplifier, peak detector, attenuator, and meter circuit. A block diagram of the instrument is shown in Figure 4-1. The oscillator circuit uses a modified Wein bridge network to generate a stable, distortionless sine wave signal which is applied to the power amplifier circuit. The peak detector circuit provides a degenerative feedback voltage to the oscillator circuit to stabilize the signal applied to the power amplifier. The power amplifier circuit is used to increase the output power available at the 50-ohm and 600-ohm output connectors and to improve the frequency stability of the output signal with changing output loads. The output attenuator provides a means of attenuating the signal at the output connectors in nine steps of 10 db each. The metering circuit continuously monitors the signal level at the input to the attenuator. The regulated power supply provides all voltages required by the Test Oscillator circuits.

4-3. CIRCUIT DESCRIPTION.

4-4. OSCILLATOR CIRCUIT.

4-5. The oscillator circuit generates a sinusoidal signal at the frequency selected by the RANGE switch and FREQUENCY Dial located on the front panel. The RC bridge network is a modified Wein bridge circuit consisting of an RC frequency selective network and a resistive voltage divider network. The Wein bridge in the Model 651A Test Oscillator differs from the conventional Wein bridge circuit in the design of the resistive voltage divider network. This difference is illustrated in the simplified schematic diagram of Figure 4-3. The resistor in the conventional Wein bridge is replaced with impedance Z1.

4-6. Oscillation at the selected frequency is made possible by the use of both regenerative feedback (+ feedback) and degenerative feedback (- feedback) as shown in Figure 4-3. Positive feedback is provided through a frequency sensitive RC network to the differential amplifier A2Q2 and A2Q3; negative feedback is provided to the differential amplifier through a network insensitive to frequency. Only at the selected frequency will the positive feedback exceed the negative feedback voltage to sustain oscillation.

4-7. The RANGE switch S1 selects combinations of resistors S1R1 through S1R24 to establish the frequency sensitive RC networks for the six frequency ranges of the test oscillator. The FREQUENCY Dial varies the main frequency tuning elements C1A, C1B, and C1C. The RC components maintain the proper phase relationship of the positive feedback voltage. When $X_c = R$, the positive feedback voltage is in phase with the oscillator output voltage (refer to Figure 4-2) and exceeds the negative feedback voltage. At frequencies other than where $X_c = R$, the positive feedback voltage is neither of the right phase nor of sufficient amplitude to maintain oscillations.

4-8. The impedance converter transistor A2Q1 provides a high impedance in series with the input impedance of the differential amplifier on the first four frequency ranges (X10 - X10K). The high impedance added prevents the RC bridge circuit from being loaded by the low input impedance of the differential amplifier A2Q2 and A2Q3 on the lower frequency ranges. The impedance converter is bypassed on the X100K and X1M range due to lower resistor values in the RC bridge.

4-9. The difference between the feedback voltages from the bridge circuit is amplified by differential amplifier A2Q2 and A2Q3 and is applied to the complementary symmetry circuit A2Q5 and A2Q6 through emitter follower A2Q4. A positive feedback voltage from the output of the complementary symmetry circuit is applied between resistors A2R8 and A2R9 in the collector circuit of A2Q2 on the first four frequency ranges (refer to Figure 4-3). The application of the feedback voltage at this point is used to make the effective resistance of the collector load higher than the input impedance of the emitter follower A2Q4, thus increasing the signal level at the base of the emitter follower. The increase in the signal level results in an increase in the loop gain of the oscillator circuit. The feedback voltage is removed on the X100K and X1M frequency range due to the ohmic value of resistors A2R8 and A2R9 exceeding the input impedance of the emitter follower at the higher frequencies.

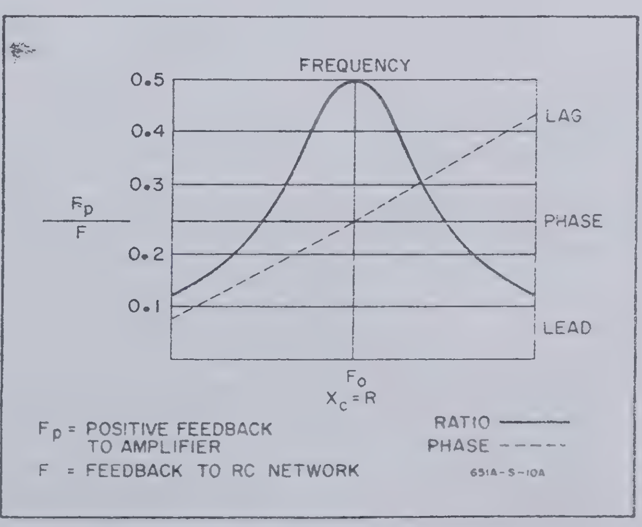


Figure 4-2. RC Network Characteristics

4-10. The complementary symmetry circuit is used to provide power gain and to increase the dynamic voltage range of the oscillator; also, the low output impedance of the complementary symmetry circuit prevents the oscillator output circuit from being loaded by the RC bridge. The complementary symmetry circuit transistors are forward-biased by diodes A2CR2, A2CR3, and A2CR4 and under a no-signal condition are conducting slightly to reduce cross-over distortion in the output signal.

4-11. The output of the oscillator circuit drives the power amplifier with a constant voltage set by the AMPLITUDE control R2. The voltage level applied to the power amplifier is held constant by the action of the peak detector circuit.

4-12. PEAK DETECTOR.

4-13. The peak detector circuit provides a bias voltage proportional to the oscillator circuit output, to control the dynamic resistance of diodes A2CR6 and A2CR7 (refer to Figure 4-3). The peak detector A2Q7 conducts only on the positive peaks of the oscillator output signal. When the positive peaks of the oscillator output exceed a set level, the peak detector conducts, breaking down the reference diode A2CR5. The breakdown of the reference diode causes a reduction in the forward bias on the RC bridge voltage divider A2CR6 and A2CR7. The decrease in forward bias causes the diodes to conduct less, increasing the dynamic resistance, and thus increasing the impedance Z1. The increase in impedance Z1 increases the amount of negative feedback voltage to the differential amplifier A2Q2 and A2Q3 which results in a reduction of the oscillator output signal. The reduction in signal level compensates for the initial increase in the oscillator output.

4-14. POWER AMPLIFIER.

4-15. The power amplifier circuit increases the power gain of the signal received from the oscillator circuit. The operation of the differential amplifier A2Q8 and A2Q9, emitter follower A2Q10, and complementary symmetry circuit A2Q11 and A2Q12 is similar to the corresponding stages in the oscillator circuit. The negative feedback voltage from the output of the complementary symmetry circuit is applied to the differential amplifier at a fixed level to stabilize the power amplifier output signal. The power amplifier output is continuously monitored by the metering circuit before the signal is applied to the output connectors through the output attenuator circuit.

4-16. METERING CIRCUIT.

4-17. The metering circuit monitors the signal level applied to the output attenuator circuit and provides a front panel readout of the signal level in rms volts and dbm. The amplifier A1Q9 serves both as an impedance converter between the voltmeter circuit and the power amplifier output circuit and as a current source to provide full-scale meter deflections. The high input impedance of the amplifier prevents the power amplifier from being loaded with the low impedance of the voltmeter M1. The emitter follower A1Q8 provides a positive feedback voltage which is applied between resistors A1R18 and A1R19 in the collector lead of amplifier A1Q9 (refer to Figure 4-4). The application of the feedback voltage at this point is used to increase the effective resistance of the collector circuit, which results in the amplifier A1Q9 appearing as a high impedance current source to the voltmeter circuit. The diode A1CR10 provides a small amount of forward bias to the rectifier diodes A1CR8 and A1CR9, which keeps the diodes out of nonlinear region thus increasing meter accuracy at one-tenth full-scale readings. The 10 Mc adjustment A1C15 compenstaes for small variations in circuit capacitance so the voltmeter will have a flat frequency response. The meter calibration resistor A1R23 provides an additional calibration adjustment which is set at 400 cps before the 10 Mc adjustment is made.

4-18. The voltmeter M1 indicates the rms value of voltage and the power level in dbm for resistive loads of 50 ohms. The output voltage level is obtained by multiplying the meter scale reading by the meter scale multiplier which appears on the OUTPUT ATTENUATOR switch. Use the following equation and the impedance correction graph of Figure 4-4 to obtain the Model 651A output power level in dbm for loads other than those marked on the output connectors.

$$\text{Output Voltage} = \frac{R_L}{R_L + R_S} \times 2V_m$$

Where,

R_L = Load Resistance (Terminating Resistance)

R_S = Source Resistance (Output Impedance of Oscillator)

V_m = Model 651A Output Meter Reading

Problem: A 600 ohm load is placed on the 50 Ω output connector and the Model 651A Output Meter indicates an output voltage of 0.9 volt with the OUTPUT ATTENUATOR set on the 1.0 volt (+10 dbm) range. Find the actual output voltage and power level (in dbm) of the Model 651A.

Solution: The actual output voltage is calculated as follows:

$$\text{Output Voltage} = \frac{600}{600 + 50} \times 2\,(0.9) = 1.66 \text{ volts}$$

The indicated power level would be 17.3 dbm for an output voltage of 1.66 volts on the 3.0 volt (+20 dbm) range. The actual power level is the algebraic sum of the indicated power level and the correction factor obtained from the impedance graph of Figure 4-4. For this example, a correction of -10.8 dbm is obtained for a 600 ohm load. The actual power level is +6.5 dbm [17.3 dbm + (-10.8 dbm)] .

4-19. OUTPUT ATTENUATOR.

4-20. The output attenuator provides a means of attenuating the signal level applied to the 50-ohm and 600-ohm output connectors. The OUTPUT ATTENUATOR switch A3S1 (refer to Figure 5-8) selects a combination of three resistor delta networks to produce the desired level of signal attenuation. Each step pro-

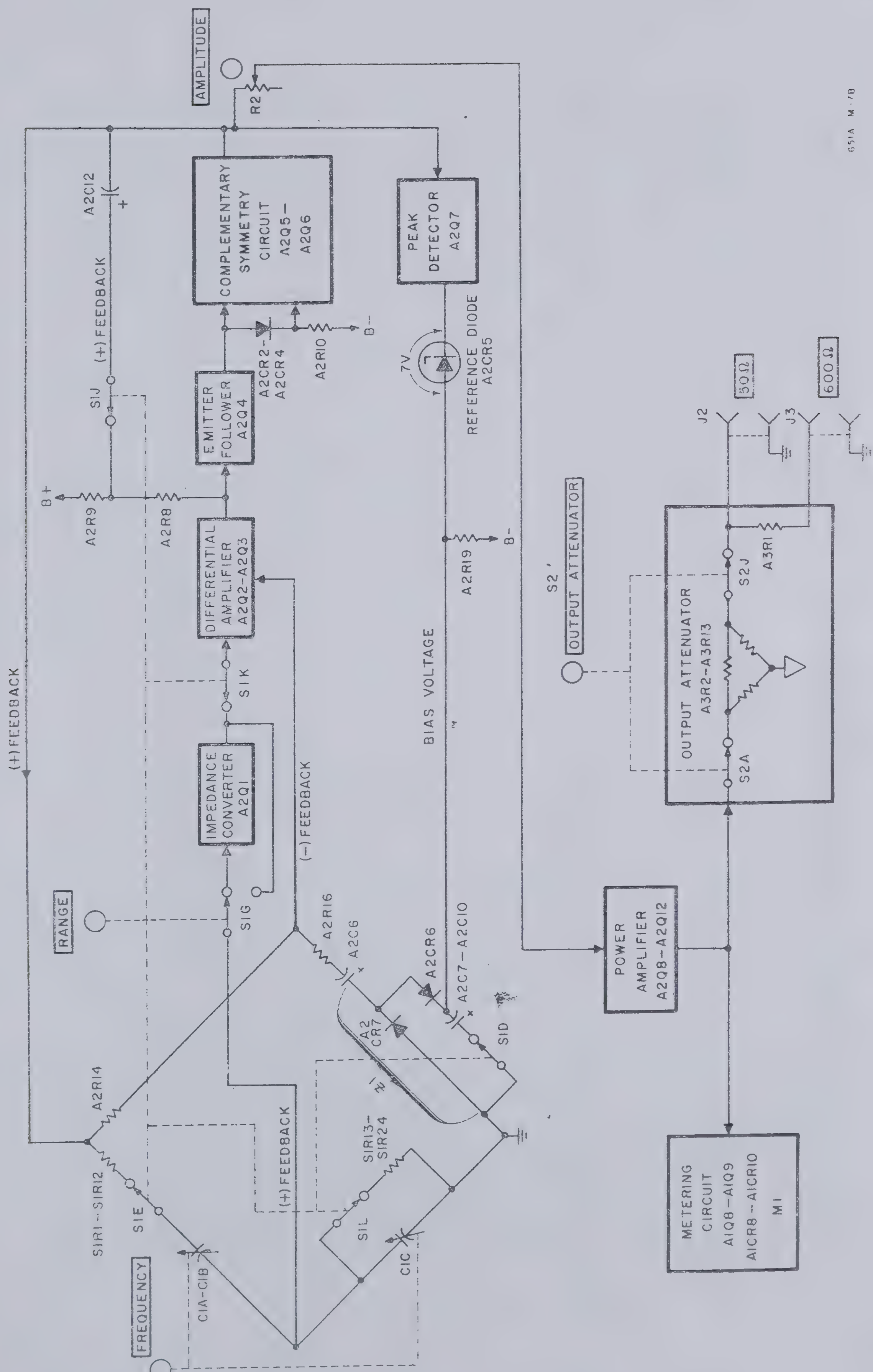


Figure 4-3. Model 651A Simplified Schematic

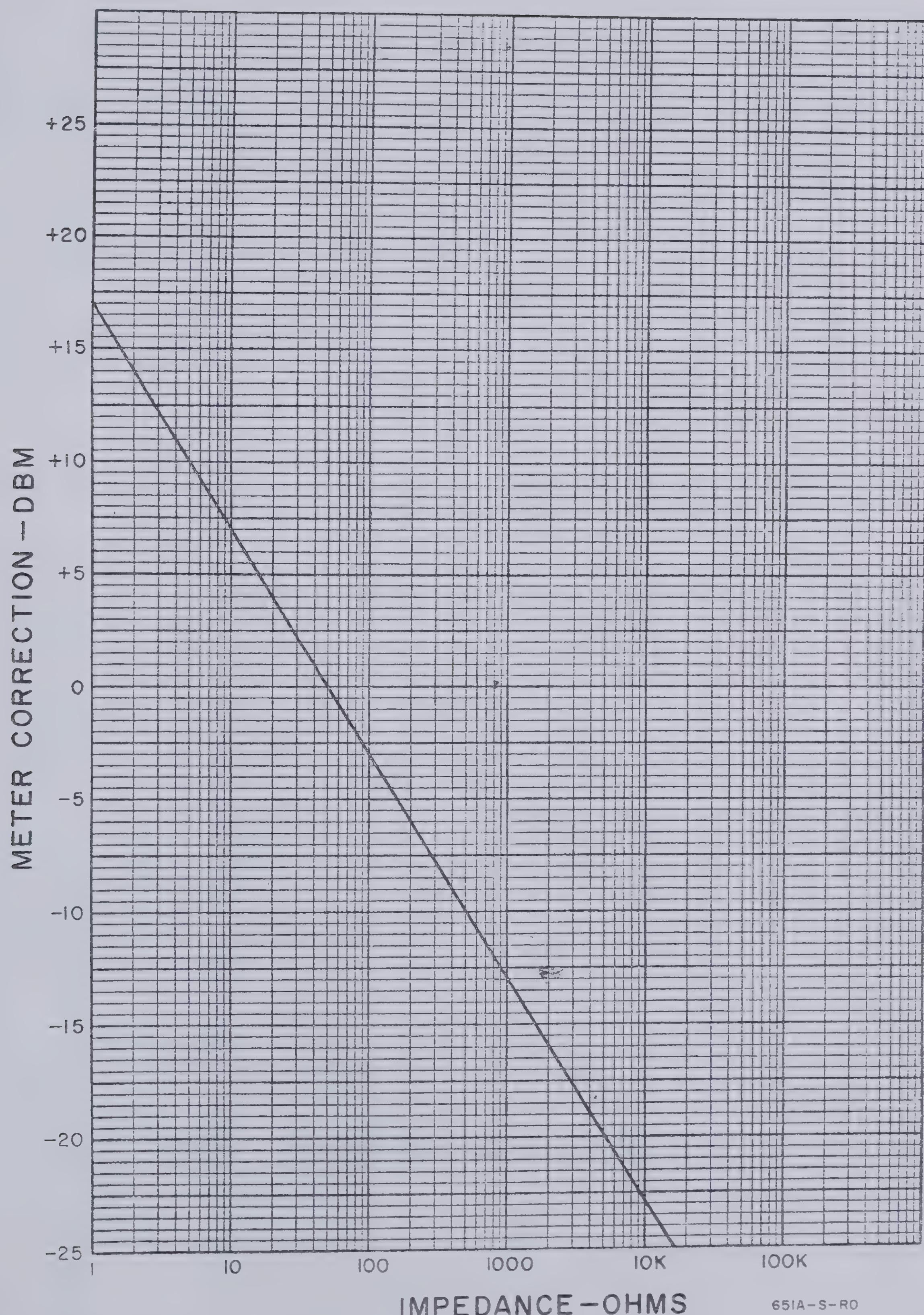


Figure 4-4. Impedance Correction Graph

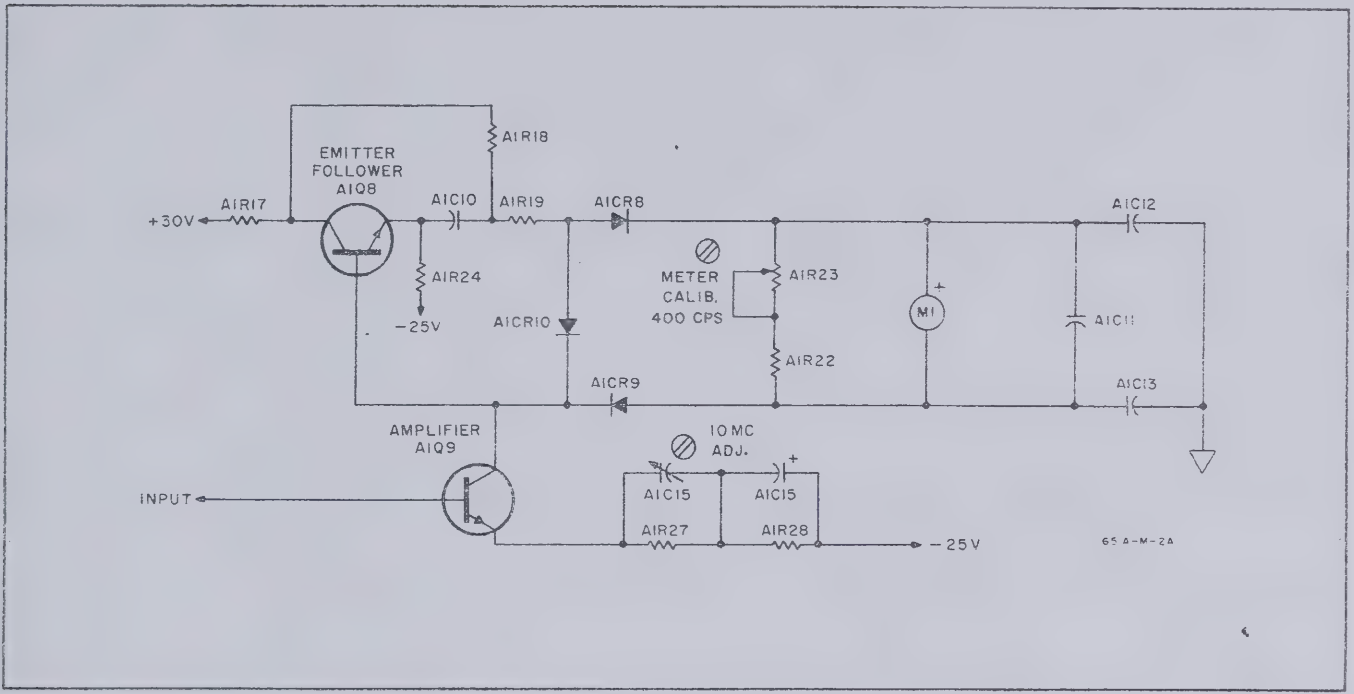


Figure 4-5. Simplified Metering Circuit

vides an attenuation of 10 db. The AMPLITUDE control R2 continuously varies the level of attenuation in increments between each 10 db step selected by the OUTPUT ATTENUATOR switch.

4-21. An output impedance other than the 50- and 600-ohm can be gained by changing the value of resistor A3R1. The value of the resistor replacing A3R1 is added to the 50-ohm oscillator output impedance to obtain the new output impedance level at the 600-ohm connector.

4-22. REGULATED POWER SUPPLY.

4-23. The regulated power supply provides all voltages required by the test oscillator circuits. The power supply consists of a +30 volt series regulated supply and a -25 volt series regulated supply which is referenced to the +30 volt circuit.

4-24. The +30 volt regulated supply is of the conventional series regulator type (refer to Figure 5-9). The emitter follower A1Q2 is used to increase the loop gain of the circuit thus improving voltage regulation. The +30 volt adjustment A1R4 sets the +30 volt and -25 volt supply output level.

4-25. The -25 volt regulated supply is of the conventional series regulator type and operates the same as the +30 volt supply. A current limiter A1Q7 has been added to limit the load current to a set value. When the load current exceeds the set value, the current limiter conducts, causing the series regulator A1Q4 to reduce the output voltage level until the load causing an excessive current is removed. Diodes A1CR6 and A1CR7 (refer to Figure 5-9) protect the control transistor A1Q6 against short circuits between the two voltage supplies and in the output of the -25 volt supply.

Table 5-1. Test Equipment

Instrument Type	Required Characteristics	Use	Recommended Model
Oscilloscope	Passband: 10 cps to 10 Mc Sensitivity: 50 mv/cm Input Impedance: 1 Megohm	Waveform Measurement	hp Model 175A
Electronic Counter	Counting Range: 10 cps to 10 Mc Accuracy: ±5 counts	Frequency Measurements	hp Model 524D
AC Voltmeter	Frequency Range: 10 cps to 10 Mc Voltage Range: 1 mv to 6.32 volts Accuracy: ±1%	AC Voltage Measurements	hp Model 3400A (with known accuracy)
Distortion Analyzer	Measure Distortion to -42 db at 20 kc	Distortion Measurements	hp Model 330B/C/D
Attenuator	Attenuation: 90 db in 10 db steps Accuracy: 90 db range less than ±0.1 db from 10 cps to 10 Mc Impedance: 50 ohms	Attenuation Check	hp Model 355D
Amplifier	Gain: 40 db Frequency Range: 10 cps to 10 Mc Noise Referred to Input: 40 db gain, 40 µv	Attenuation Check	hp Model 461A
DC Voltmeter	Voltage Range: Positive and Negative voltages from 1 mv to 30 volts Input Impedance: 1 Megohm Accuracy: ±0.3%	DC Voltage Measurements	hp Model 3440A with hp Model 3443A Plug-in
50-ohm Feed-through Load	Impedance: 50 ohms	Terminating Load	hp Model 11048B
Thermocouple	Voltage Rating: 3 volts	Frequency Response Check	hp Model 11049A
Soldering Iron and Tips	Wattage Rating: 50 watts Min tip temp: 700°F T. P. Size O. D. 1/16" to 3/32"	Repair	Ungar #776 Soldering Iron Handle Ungar #PL333 Tiplet Ungar #854 Cup Tip Ungar #855 Cup Tip
Variable Line Transformer	Voltage Range: 103 - 128 vac Power Capability: 20 watts	Power Supply Tests	Superior Type UC1M

SECTION V
MAINTENANCE

5-1. TEST EQUIPMENT.

5-2. Any instrument which satisfies the specifications of Table 5-1 can be used for the test described in this maintenance section.

5-3. PERFORMANCE CHECKS.

5-4. The performance checks are in-cabinet checks that insure that Model 651A Test Oscillator is operating within specifications. These checks may be used as an incoming inspection, periodic maintenance, or after repair check. Use these performance checks to verify instrument performance before making internal adjustments or repairs. These checks are made with the ac power cord connected to 115/230 vac, 50 - 1000 cps line voltage unless otherwise specified.

5-5. DIAL ACCURACY CHECK.

a. Connect Model 651A as shown in Figure 5-1.

b. Set Model 651A controls as follows:

FREQUENCY RANGE	X10
FREQUENCY Dial	1
OUTPUT ATTENUATOR . .	3. 0 v
AMPLITUDE.	Adjust for 3. 0 volts on 3-volt scale

c. Set Electronic Counter controls as follows:

FUNCTION SELECTOR. . .	10 PERIOD AVERAGE
FREQUENCY UNIT.	1 SECOND
TIME UNIT	MILLISECONDS
DISPLAY TIME	1/4 turn cw from INF

d. Electronic Counter should read 100 ±3 ms.

e. Set FREQUENCY Dial to 5. Electronic Counter should read 20 ±0. 6 ms.

f. Set FREQUENCY Dial to 10. Electronic Counter should read 10. 0 ±0. 3 ms.

g. Set FREQUENCY RANGE to X100 and FREQUENCY Dial to 1, Electronic Counter should read 10. 0 ±0. 2 ms.

h. Repeat steps e and f with FREQUENCY RANGE at X100, Electronic Counter should read 2. 00 ±0. 04 ms and 1. 00 ±0. 02 ms respectively.

i. Set Electronic Counter FUNCTION SELECTOR to FREQUENCY.

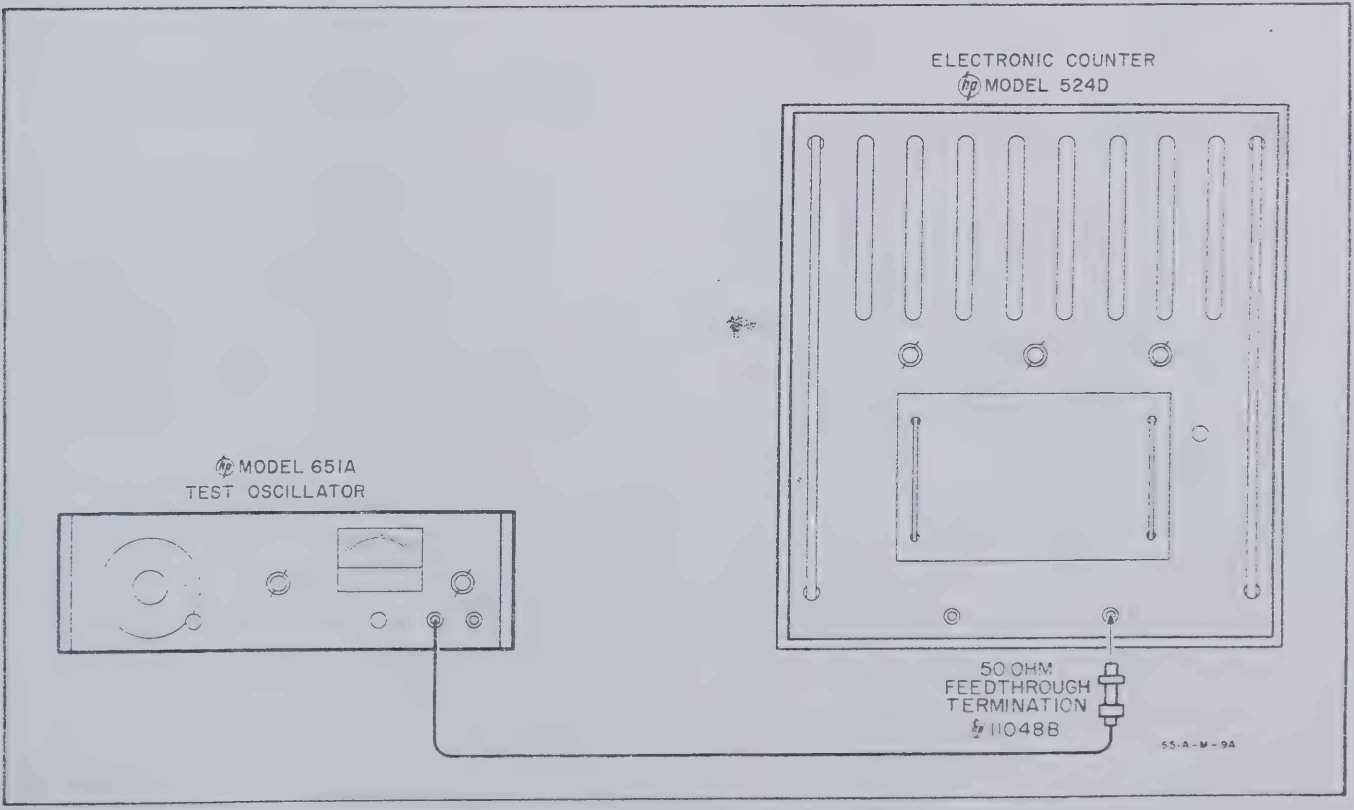


Figure 5-1. Dial Accuracy Check

j. Complete check by setting Test Oscillator FREQUENCY RANGE switch and FREQUENCY Dial as shown in Table 5-2, columns one and two. The Electronic Counter reading should be as shown in column three.

Table 5-2. Dial Accuracy

FREQUENCY RANGE	FREQUENCY Dial	COUNTER READING
X1K	1	1000 cps ±20 cps
X1K	5	5000 cps ±100 cps
X1K	10	10 kc ±0. 2 kc
X10K	1	10 kc ±0. 2 kc
X10K	5	50 kc ±1. 0 kc
X10K	10	100 kc ±2. 0 kc
X100K	1	100 kc ±2. 0 kc
X100K	5	500 kc ±10 kc
X100K	10	1 Mc ±20 kc
X1M	1	1 Mc ±30 kc
X1M	5	5 Mc ±150 kc
X1M	10	10 Mc ±300 kc

5-6. OUTPUT METER CHECK.

a. Connect Model 651A as shown in Figure 5-2.

NOTE

Use a Model 3400A with known accuracy.

b. Set Model 651A controls as follows:

FREQUENCY RANGE. X100
FREQUENCY Dial 4
OUTPUT ATTENUATOR . . . 3.0 v

c. Set RMS Voltmeter RANGE switch to 3-volt range.

d. Adjust Test Oscillator AMPLITUDE control for 3. 0-volt reading on Model 651A output meter. RMS Voltmeter should read 3. 0 volts ±2% (0. 06 volt).

e. Turn AMPLITUDE control fully CCW. RMS Voltmeter reading should drop to zero.

NOTE

The Model 651A output meter may typically have an offset of one division (up-scale reading) on the top voltage scale.

5-7. AMPLITUDE CONTROL AND OUTPUT VOLTAGE CHECK.

a. Connect Model 651A as shown in Figure 5-2.

b. Set Model 651A controls as follows:
FREQUENCY RANGE. . . . X1K
FREQUENCY Dial 10
OUTPUT ATTENUATOR . . 3.0 v

c. Set RMS Voltmeter RANGE switch to 3-volt range.

d. Adjust Test Oscillator AMPLITUDE control for 3-volt reading on RMS Voltmeter.

e. Turn AMPLITUDE control fully ccw. Reading on RMS Voltmeter should be reduced to at least 0. 3 volts (20 db down).

f. Set RMS Voltmeter RANGE switch to 10-volt range.

g. Turn AMPLITUDE control on Test Oscillator fully cw. Reading on RMS Voltmeter should be at least 3. 16 volts.

h. Repeat steps a through g for 600-ohm output connector and replace 50-ohm load with a 600-ohm load. Reading on RMS Voltmeter should be at least 3. 16 volts.

5-8. OUTPUT IMPEDANCE CHECK.

a. Connect Model 651A 50-ohm output directly to input of Model 3400A.

b. Set Model 3400A RANGE switch to 10-volt range.

c. Set Model 651A controls as follows:

FREQUENCY RANGE. X1K
FREQUENCY Dial 1
OUTPUT ATTENUATOR . . . 3.0 v

d. Set AMPLITUDE control on Test Oscillator for a 6. 0 volt reading on RMS Voltmeter.

e. Insert 50-ohm feedthrough load between Test Oscillator and RMS Voltmeter. Reading on RMS Voltmeter should be 3. 00 ±0. 15 volt.

f. Repeat steps a through e using 600-ohm output connector and a 600-ohm load. Reading on RMS Voltmeter, with 600-ohm load inserted, should be 3. 0 ±0. 1 volt.

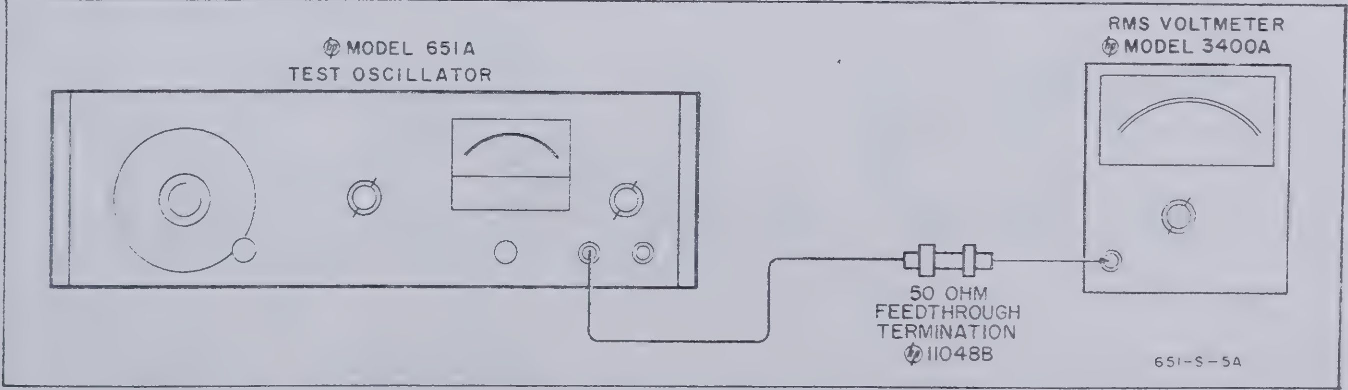


Figure 5-2. Output Meter, Amplitude Control, Output Voltage, and Hum and Noise Check

5-9. HUM AND NOISE CHECK.

a. Connect Model 651A as shown in Figure 5-2.

b. Set Model 651A controls as follows:

FREQUENCY RANGE. X100
FREQUENCY Dial 10
OUTPUT ATTENUATOR . . . 3.0 v

c. Set RANGE switch on RMS Voltmeter to 3-volt range.

d. Adjust Test Oscillator AMPLITUDE control for 0 db on RMS Voltmeter.

e. Turn LINE switch off and remove cover on Test Oscillator (refer to Paragraph 5-17) and connect a short lead from FRAME of main tuning capacitor C1 to chassis.

f. Replace top cover and turn LINE switch ON.

g. Set RANGE switch on RMS Voltmeter to obtain an up-scale reading.

h. Residual hum and noise should be -66 db from reference.

i. Remove shorting lead from frame of main tuning capacitor.

5-10. OUTPUT METER FLATNESS CHECK.

a. Connect Model 651A as shown in Figure 5-3.

NOTE

Connect Thermocouple directly to 50-ohm output connector.

b. Set Model 651A controls as follows:

FREQUENCY RANGE. X1K
FREQUENCY Dial 10
OUTPUT ATTENUATOR . . . 3.0 v

c. Set Digital Voltmeter controls as follows:

RANGE . . . . 100 mv
SAMPLE RATE. . . . . MAXIMUM

d. Adjust Test Oscillator AMPLITUDE control for 3.0 volt reading on 3.0 volt scale of output meter. Record reading obtained on Digital Voltmeter and use as a reference in the following step.

e. Check output meter flatness on each frequency range with FREQUENCY Dial settings of 1, 5, and 10. Adjust Test Oscillator AMPLITUDE control at each frequency setting until the reference voltage obtained in step d is obtained on the Digital Voltmeter. Read error on Model 651A output meter. Table 5-3 gives FREQUENCY RANGE switch and FREQUENCY Dial setting with the tolerance for each setting.

Table 5-3. Output Meter Flatness Check

FREQUENCY RANGE	FREQUENCY Dial	OUTPUT METER ERROR
X10	1-2	±2% (0.06 volt)
X10	2-10	±1% (0.03 volt)
X100	1-10	±1% (0.03 volt)
X10K	1-10	±1% (0.03 volt)
X100K	1-10	±1% (0.03 volt)
X1M	1-4	±1% (0.03 volt)
X1M	4-10	±2% (0.06 volt)

5-11. INSTRUMENT FREQUENCY RESPONSE CHECK.

a. Connect Model 651A as shown in Figure 5-3.

b. Set Model 651A controls as follows:

FREQUENCY RANGE. X1K
FREQUENCY Dial 10
OUTPUT ATTENUATOR . . . 3.0 v

c. Set Digital Voltmeter controls as follows:

RANGE . . . . 100 mv
SAMPLE RATE. . . . . MAXIMUM

d. Adjust AMPLITUDE control for 3.0 v reading on output voltmeter. Reading on Digital Voltmeter should be approximately 7.00 mv. Record reading.

NOTE

This establishes a reference voltage. Do not adjust the AMPLITUDE control during the remainder of these checks.

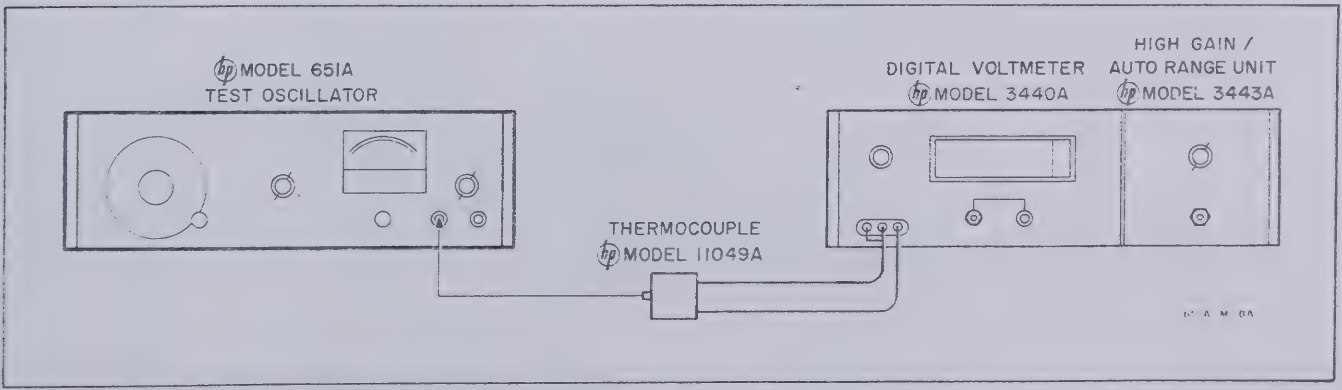


Figure 5-3. Output Meter Flatness and Instrument Frequency Response Check

e. Sweep FREQUENCY Dial slowly from 1 to 10. Digital Voltmeter reading should not vary more than ±4% from the reference voltage set in step d as the dial is turned from 1 to 10.

NOTE

The percent of voltage change in the test oscillator output, as read on the Digital Voltmeter, is doubled due to the thermocouple being a square law device: therefore, the error read will be twice the value specified in Table 1-1.

f. Set Model 651A FREQUENCY RANGE to X10 and FREQUENCY Dial to 1.

g. Repeat step e. Digital Voltmeter reading should not vary more than ±6% from reference set in step d.

h. Repeat step e with FREQUENCY RANGE set at X100, X10K, X100K, and X1M. The Digital Voltmeter reading should be within ±4% for (1 kc to 1 Mc) and ±8% (for 1 Mc to 10 Mc) of reference set in step d.

NOTE

There will typically be a 3 db roll-off in the output signal at 10 Mc as measured with an hp Model 411A RF Millivoltmeter connected directly to the 600 Ω output connector.

5-12. DISTORTION CHECK.

a. Connect Model 651A as shown in Figure 5-4.

b. Set Model 651A controls as follows:

FREQUENCY RANGE. . . . X1K
FREQUENCY Dial 1
OUTPUT ATTENUATOR . . 3.0 v

d. Adjust AMPLITUDE control for 3.0 volt reading on Output Meter.

d. Set Distortion analyzer controls as follows:

FREQUENCY RANGE. X10
FUNCTION SWITCH . . . . . SET LEVEL
METER RANGE SWITCH. . . 100%

e. Make following adjustments on distortion analyzer.

(1). Adjust INPUT SENSITIVITY control for full-scale meter reading.

(2). Set meter FUNCTION switch to DISTORTION.

(3). Adjust COARSE and FINE FREQUENCY controls and BALANCE control for dip or null (on distortion analyzer meter) at fundamental frequency (1 kc). Switch METER RANGE switch as necessary to obtain upscale meter reading.

(4). Readjust FREQUENCY and BALANCE controls until maximum meter dip or null is obtained.

f. Read percent distortion on meter scale selected by METER RANGE switch. Distortion should be less than 1%.

g. Repeat steps b, c, and d using Table 5-4 for setting Model 651A controls. Distortion for frequencies obtained should be less than 1%.

Table 5-4. Distortion Check

FREQUENCY RANGE	FREQUENCY Dial
X10	1
X10	10
X100	1
X100	10
X1K	1
X1K	10
X10K	1
X10K	2

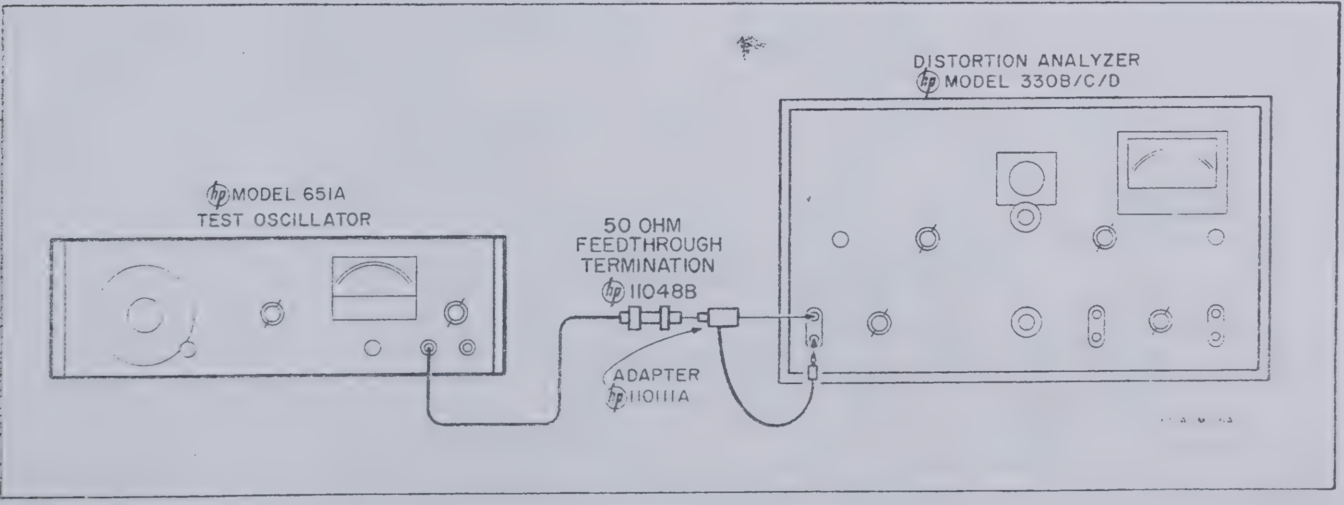


Figure 5-4. Distortion Check

5-13. ATTENUATION CHECK.

a. Connect Model 651A as shown in Figure 5-5. Use a Model 355D Attenuator with a known accuracy (within ±0.02 db). Use a short (6 - 12 inches) RG-223/U cable between Test Oscillator and Attenuator. Use short cables (6 - 12 inches) between Attenuator, Amplifier, and RMS Voltmeter.

NOTE

Float the Amplifier and RMS Voltmeter by using a three-prong to two-prong adapter on the ac power cord of both instruments.

b. Set Model 651A controls as follows:

FREQUENCY RANGE X1K
FREQUENCY Dial 1
OUTPUT ATTENUATOR. . . . +20 db (3.0 v)

c. Set Model 355D attenuator switch to 90 db position.

d. Set Model 461A gain switch to 40 db position.

e. Set Model 3400A RANGE switch to 0.01 volt range (0.003 volt RANGE for Option 02).

f. Adjust AMPLITUDE control on Test Oscillator for a 0.9 reference on the RMS Voltmeter with Test Oscillator set for 1 kc output.

g. Check attenuator on each range by removing attenuation from the Model 355D as the attenuation is increased on the Model 651A. Reading on Model 3400A should read within ±1% (0.1 db) of reference in step f.

h. Repeat steps f and g with test oscillator set for 1 Mc output. Reading on Model 3400A should read within ±1% (0.1 db).

i. Repeat steps f and g with test oscillator set for 100 kc, 5 Mc, and 10 Mc. Reading on Model 3400A should read within ±1% (0.1 db).

j. Check Option 02 Attenuation by adding a two resistor (43.2 ohm and 86.6 ohm) impedance converter across the 75 Ω output connector. Connect the 43.2 ohm resistor to A3R14 and the 86.6 ohm resistor to ground. Use test setup in Figure 5-5 with the Model 355D connected across the 86.6 ohm resistor.

5-14. ADJUSTMENT AND CALIBRATION PROCEDURES.

5-15. METER MECHANICAL ZERO.

5-16. The meter is properly zero-set when the meter pointer rests over the zero mark on the meter scale and when the Test Oscillator is 1) in normal operating position, 2) at normal operating temperature, and 3) is turned off. Zero-set meter as follows to obtain maximum accuracy and mechanical stability.

a. Allow the Test Oscillator to operate for at least 20 minutes; this allows the meter movement to reach normal operating temperature.

b. Turn Test Oscillator off and allow 30 seconds for all capacitors to discharge.

c. Rotate mechanical zero-adjustment screw cw until the meter pointer is to the left of zero and moving upscale toward zero.

d. Continue to rotate adjustment screw cw; stop when meter pointer is on the zero line. If the meter pointer overshoots zero, repeat steps c and d.

e. When the meter pointer is exactly on zero, rotate the adjustment screw approximately 15 degrees ccw to free the adjustment screw from the meter suspension. If the meter pointer moves during this step, repeat steps c through e.

5-17. COVER REMOVAL AND REPLACEMENT.

5-18. Removal of the top cover exposes circuit areas for routine checks and adjustments and removal of the bottom cover exposes circuit areas for operations such as soldering, component replacement etc.

5-19. TOP AND BOTTOM COVER REMOVAL:

a. Remove two retaining screws from top of cover.

b. Grasp cover from the rear, slide it back 1/2 inch, then tilt forward edge of cover upward and lift from instrument.

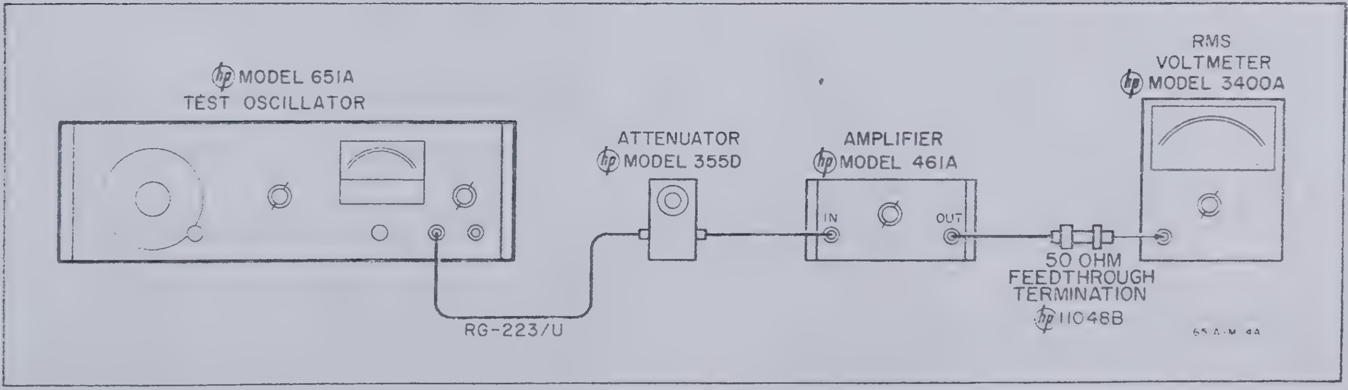


Figure 5-5. Attenuation Check

5-20. TOP AND BOTTOM COVER REPLACEMENT:

a. Rest cover flat on cast guides projecting inward near top of each side frame.

b. Slide cover forward allowing forward edge to enter groove in front panel.

c. Replace two cover retaining screws.

5-21. The four side covers are removed by turning out the two retaining screws in each cover.

5-22. POWER SUPPLY VOLTAGE ADJUSTMENT AND CHECK.

a. Remove bottom cover to expose power supply circuit board.

b. Set DC Voltmeter (Model 412A) controls as follows:

FUNCTION.	VOLTS
RANGE.	30 v
POLARITY.	(+)

c. Connect DC Voltmeter to positive supply output (connector point 1). Refer to Figure 5-9.

d. Turn Test Oscillator LINE switch ON.

e. Adjust A1R4 for a DC Voltmeter reading of +30 v.

f. Set DC Voltmeter POLARITY control to (-) and connect VOLTS probe to -25 volt supply output (connector point 2). DC Voltmeter should read -25 v ±0. 75 volts.

NOTE

If negative supply output is not -25 ±0. 75 volts, change the value of resistor A1R13 to obtain specified supply voltage.

g. If supply voltages cannot be adjusted according to steps d through f, turn Test Oscillator LINE switch off, and remove power supply leads from oscillator circuit board connectors 2, 3, 6, and 8 (refer to Figure 5-8) to isolate power supply.

h. Turn LINE switch ON and check power supply voltages by repeating steps d and f.

i. If voltages do not meet values specified, troubleshoot power supply to remove malfunction.

j. If power supply voltages come up to values specified in steps d and f, the malfunction is either in the oscillator circuit or power amplifier circuit or both.

k. To isolate malfunction to either oscillator circuit or power amplifier circuit, connect power supply leads to oscillator circuit board connectors 2 and 8 (oscillator circuit) and observe readings on DC Voltmeter. If trouble in step g returns, troubleshoot oscillator circuit. Replace connectors 3 and 6 (power amplifier circuit). If trouble returns, troubleshoot power amplifier circuit.

5-23. POWER SUPPLY REGULATION CHECK.

a. Apply power to Model 651A through a Variable Line Supply.

b. Adjust line voltage to 115 vac.

c. Connect Model 412A DC Voltmeter to negative supply output connector point 2 (refer to Figure 5-9) and note DC Voltmeter reading.

d. Vary line voltage from 103. 5 vac to 126. 5 vac noting change in DC Voltmeter reading. Reading should be within ±0. 5 volt from reference established in step c.

5-24. POWER SUPPLY RIPPLE CHECK.

a. Rotate RMS Voltmeter (hp Model 3400A) RANGE switch to 0. 01 volt range.

b. Connect RMS Voltmeter to negative supply output connector point 2 (refer to Figure 5-9).

c. Apply power to Model 651A through a Variable Line Supply.

d. Adjust line voltage to 103. 5 vac.

e. Read ripple voltage on RMS Voltmeter. Ripple voltage should be less than 6 millivolts. If ripple voltage exceeds 6 millivolts stop oscillations by placing hand on tuner capacitor frame. If ripple voltage still exceeds 6 millivolts, troubleshoot power supply according to Troubleshooting Table 5-6.

5-25. X1K RANGE FREQUENCY DIAL CALIBRATE.

a. Remove bottom cover from Test Oscillator (refer to Cover Removal and Replacement, Paragraph 5-17).

b. Remove oscillator circuit shield by turning out six retaining screws.

c. Attach a test lead to test point A2TP2.

NOTE

Connect test lead so voltage at A2TP2 can be monitored with bottom cover and oscillator shield in place.

d. Connect Model 412A DC Voltmeter between test lead attached to A2TP2 in step c and ground (connector point 7 or 19).

e. Set Model 412A controls as follows:

FUNCTION.	VOLTS
RANGE.	1 volt
POLARITY.	(-)

f. Set Model 651A controls as follows:

FREQUENCY RANGE . .	X1K
FREQUENCY Dial. . . .	max cw
AMPLITUDE.	max cw
OUTPUT ATTENUATOR.	3. 0 v

g. Connect Model 651A to Distortion Analyzer as shown in Figure 5-4.

h. Measure distortion following steps d and e of Distortion Check (Paragraph 5-12).

i. Adjust A2R17 for minimum distortion.

NOTE

This adjustment is a preliminary adjustment for frequency calibration. Distortion should be less than 1% (42 db down).

j. Connect RMS Voltmeter (hp Model 3400A) between A2TP1 and ground with RMS Voltmeter RANGE switch set on 0. 3 volt range. RMS Voltmeter reading should be 110 ±10 millivolts (gain control voltage).

NOTE

If necessary, change value of resistor A2R16 to obtain specified gain control voltage.

k. Record voltage at A2TP2 as monitored on DC Voltmeter.

NOTE

This voltage is directly related to the gain control voltage at A2TP1 and is used as a reference in the following calibration procedures.

l. Replace bottom cover and oscillator circuit shield leaving lead connected to DC Voltmeter.

m. Connect output of Test Oscillator to Electronic Counter as shown in Figure 5-1. Refer to Paragraph 5-5 for Electronic Counter control settings.

n. Turn FREQUENCY Dial on Test Oscillator to extreme ccw position.

o. Adjust S1C2 and S1C7 alternately until Test Oscillator output frequency is 10. 2 kc and voltage at A2TP2 is the same as recorded in step k.

p. Turn FREQUENCY Dial to extreme cw position and read Test Oscillator output frequency. Frequency should be 965 to 970 cps.

q. If frequency is not within 965 to 970 cps, loosen tuner coupler and slip tuner until specified frequency is obtained.

NOTE

Avoid touching tuner coupler with your fingers while performing this adjustment.

r. Set Test Oscillator frequency to 5 kc on Electronic Counter.

s. Remove FREQUENCY Dial knob and loosen four dial retaining screws.

t. Slip FREQUENCY Dial until 5 on the dial lines up with reference mark.

u. Tighten dial retaining screws; then turn FREQUENCY Dial to 10.

v. Adjust S1C2 and S1C7 alternately until frequency is 10 kc as read on Electronic Counter and the voltage at A2TP2 is the same at the top and and bottom of X1K frequency range.

NOTE

Voltage at A2TP2 will not necessarily be the same as that recorded in step k.

5-26. X100, X1K, and X10K RANGE FREQUENCY CALIBRATION AND DIAL TRACKING.

a. Connect Model 651A to Electronic Counter as shown in Figure 5-1 with DC Voltmeter monitoring voltage at A2TP2 as outlined in Paragraph 5-25.

b. Check frequency tracking of FREQUENCY Dial at 1, 1.5, 2.5, 5, 8, and 10 on X100, X1K, and X10K ranges while monitoring voltage at A2TP2 on each range. Voltage at A2TP2 should remain essentially constant from the 1-through-10 position on the FREQUENCY Dial.

c. If frequency ranges are off on the 1 position of the FREQUENCY Dial, change the value of the RANGE switch resistors associated with the respective range (refer to Table 5-5). Change value of both resistors on each range at the same time to keep voltage at A2TP2 the same on all ranges (within ±0. 01 volt from voltage obtained in Paragraph 5-25 step v).

NOTE

Keep voltage at A2TP2 constant from range to range to maintain Test Oscillator output amplitude within specifications of Table 1-1 on all ranges.

d. Dial accuracy should be within specifications in Table 1-1.

Table 5-5. Frequency Range Switch Padding Resistors

Frequency Range	Padding Resistors
X10	S1R1 and S1R14
X100	S1R3 and S1R16
X1K	S1R5 and S1R18
X10K	S1R7 and S1R20
X100K	S1R9 and S1R22
X1M	S1R11 and S1R24

5-27. X10 RANGE FREQUENCY CALIBRATION AND DIAL TRACKING.

a. Connect Model 651A to Electronic Counter as shown in Figure 5-1 with DC Voltmeter monitoring voltage at A2TP2 as outlined in Paragraph 5-25.

b. Set FREQUENCY Dial to 10 and check frequency on Electronic Counter. Frequency should be 100 ±3 cps.

NOTE
It may be necessary to split difference in frequency between ends of dial.

c. Set FREQUENCY Dial to 1 and check frequency on Electronic Counter. Frequency should be 10 ±0. 3 cps.

d. If frequency is not within specified limits of step c, change the value of resistors S1R1 and S1R14 at the same time to bring frequency within specifications and keeping voltage at A2TP2 the same as in Paragraph 5-25 step v.

e. Check frequency at 1. 5, 2. 5, 5, and 8 on FREQUENCY Dial. Dial accuracy should be within ±3%.

5-28. X1M RANGE FREQUENCY CALIBRATION AND DIAL TRACKING.

NOTE
The following adjustments are critical. Final frequency and voltage readings must be made with all instrument covers in place to meet specifications listed in Table 1-1.

a. Connect Model 651A to Electronic Counter as shown in Figure 5-1 with DC Voltmeter monitoring voltage at A2TP2 as outlined in Paragraph 5-25.

b. Set FREQUENCY Dial to 10 and adjust S1C5 and S1C10 with tuning wand until frequency on Electronic Counter is 10. 15 Mc (1. 5% high) and voltage at A2TP2 is the same as in Paragraph 5-25 step v (within ±0. 02 volts).

NOTE
To accomplish step b, remove the Test Oscillator top cover, make adjustments, then replace and check frequency dial accuracy and voltage at A2TP2.

c. If oscillator will not oscillate (no reading on output meter) or S1C5 and S1C10 do not have enough range to accomplish step b, set FREQUENCY Dial to 5, remove bottom cover. and adjust A2C5 (10 Mc Adjust) until oscillator oscillates and frequency on Electronic Counter reads 5 Mc, then repeat step b.

NOTE
Replace bottom cover to establish 5 Mc with 10 Mc Adjust A2C5.

d. Set FREQUENCY Dial to extreme ccw positon and adjust S1C10 until voltage at A2TP2 is the same as in Paragraph 5-25 step v.

e. Turn FREQUENCY Dial to 1 and check frequency on Electronic Counter. Frequency should be 1 Mc ±3% (may be about 1% high).

f. If either the frequency or voltage at A2TP2 do not adjust according to steps c through e, change values of range resistors S1R11 or S1R24 simultaneously until both frequency and voltage are within specifications.

g. Set FREQUENCY Dial to 5 and adjust A2C5 until frequency output is 4. 975 to 4. 950 Mc (0. 5 to 1. 0% low).

NOTE
Frequency reading must be made with all covers in place.

h. Recheck frequency output with FREQUENCY Dial set at 10. If necessary, readjust S1C5 and S1C10 for 10. 15 Mc reading (1. 5% high) on Electronic Counter.

i. Check dial accuracy at 1, 1. 5, 2. 5, 5, 8, and 10. Frequency readings should be within specifications listed in Paragraph 5-27 step e.

5-29. X100K RANGE FREQUENCY CALIBRATION AND DIAL TRACKING.

NOTE
The following adjustments are critical. Final frequency and voltage readings must be made with all instrument covers in place to meet specifications listed in Table 1-1.

a. Connect Model 651A to Electronic Counter as shown in Figure 5-1 with DC Voltmeter monitoring voltage at A2TP2 as outlined in Paragraph 5-25.

b. Set FREQUENCY Dial to 10 and adjust S1C4 and S1C9 with tuning wand for 1 Mc reading on Electronic Counter and voltage at A2TP2 equal to that in Paragraph 5-25 step v or within ±0. 02 volts.

c. Set FREQUENCY Dial to 1. Frequency should be 100 ±2 kc (±2%) and voltage at A2TP2 should be within ±0. 02 volt of that in Paragraph 5-25 step v.

d. If frequency reading or voltage at A2TP2 are not within specified limits of step c, change the value of range resistors S1R9 and S1R22 to bring both readings within specifications.

e. Check dial accuracy at 1, 1. 5, 2. 5, 5, 8, and 10. Frequency readings should be within specifications listed in Paragraph 5-27 step e.

NOTE
If necessary, readjust S1C4 and S1C9 to correct frequency reading at 10 on FREQUENCY Dial for this range.

5-30. 10 MC FLATNESS ADJUSTMENT.

a. Connect Model 651A as shown in Figure 5-3.

b. Set Model 651A controls as follows:

FREQUENCY RANGE.	X1K
FREQUENCY Dial	10
OUTPUT ATTENUATOR . . .	3.0 v

c. Set Digital Voltmeter controls as follows:

RANGE	100 mv
SAMPLE RATE	MAXIMUM

d. Adjust AMPLITUDE control for a 3.0 v reading on output meter. Reading on Digital Voltmeter should be approximately 7.00 mv. Record reading.

NOTE

This establishes a reference voltage. Do not adjust the AMPLITUDE control during the remainder of these checks.

e. Set Model 651A FREQUENCY RANGE to X1M.

f. Sweep FREQUENCY Dial slowly from 1 to 10. Digital Voltmeter reading should not vary more than ±8% from the reference voltage set in step d.

NOTE

The percent of voltage change in the test oscillator output, as read on the Digital Voltmeter, is doubled due to the thermocouple being a square law device; therefore the error read will be twice the value specified in Table 1-1.

g. Adjust A2C14 to reduce any voltage peaking which may be present. If necessary, A2C14 may be removed from the circuit.

5-31. OUTPUT WAVEFORM CHECK.

a. Connect 50-ohm output of Model 651A to an Oscilloscope.

b. Set OUTPUT ATTENUATOR to +20 db position.

c. Turn AMPLITUDE control to maximum cw position.

d. Check Test Oscillator output waveform, with and without load on all frequencies, for squegging and spurious oscillations on the waveform.

NOTE

Turn sweep rate on Oscilloscope to a slow rate to check for squegging of oscillator. If spurious oscillations occur, pad A2C21 until spurious oscillations are eliminated.

e. Check for microphonics by hitting instrument with palm of your hand and observing oscilloscope for microphonics.

5-32. OUTPUT METER CALIBRATION.

NOTE

The following adjustments are critical. Final voltage readings must be made with all instrument covers in place to meet specifications listed in Table 1-1.

5-33. 400 CPS METER CALIBRATION:

a. Connect Model 651A as shown in Figure 5-2 using a Model 3400A RMS Voltmeter with known accuracy.

b. Set Model 651A controls as follows:

FREQUENCY RANGE.	X100
FREQUENCY Dial	4
OUTPUT ATTENUATOR . . .	3.0 v

c. Set RANGE switch on RMS Voltmeter to 3.0 volt range.

d. Adjust AMPLITUDE control for a 3.16 volt reading on RMS Voltmeter (1.0 division on 1 volt scale).

e. Adjust meter calibrate control A1R23 for 3.16 volt reading (1.0 division on 1 volt scale) on Test Oscillator output meter.

f. Check output meter tracking by turning AMPLITUDE control ccw while observing voltage reading on RMS Voltmeter at each major voltage division on Test Oscillator output meter. Voltage readings on output meter should be within ±2% (0.06 volt).

5-34. 10 MC METER CALIBRATION:

a. Use test setup outlined in Paragraph 5-32.

b. Set Model 651A controls as follows:

FREQUENCY RANGE.	X1M
FREQUENCY Dial	10
OUTPUT ATTENUATOR . . .	3.0 v

c. Set RMS Voltmeter RANGE switch to 3 volt range.

d. Adjust AMPLITUDE control for 3.16 reading (1.0 division on 1 volt scale) on RMS Voltmeter. Output meter on Test Oscillator should read 3.16 v rms (1.0 division on 1 volt scale).

NOTE

Allow for known error of Model 3400A at 10 Mc.

e. If output meter does not read 3.16 volts, adjust A1C15 with tuning wand (10 Mc Adjust) for specified reading.

5-35. MINIMUM DISTORTION ADJUSTMENT.

a. Connect Model 651A as shown in Figure 5-4.

Table 5-6. Troubleshooting

Indication	Action
No reading on output meter (LINE switch indicator lamp not lit).	Check line fuse F1 and LINE switch S2.
No reading on output meter (LINE switch indicator lamp lit).	Check output of Test Oscillator with RMS Voltmeter or Oscilloscope.
No reading on output meter with output signal present at 50-ohm and 600-ohm connectors.	Check metering circuit (A1Q8, A1Q9, A1CR8, A1CR9, and M1). See Paragraph 5-38.
No output signal at 50-ohm and 600-ohm connectors with OUTPUT ATTENUATOR switch and FREQUENCY RANGE switch in any position.	Check regulated power supply output voltages (+30 and -25 volts).
No output from power supplies with supplies connected to Test Oscillator circuits.	Isolate power supplies from power amplifier circuit by removing connectors 3 and 6 from oscillator circuit assembly A2 (refer to Figure 5-8) and check power supply voltages. Isolate power supplies from oscillator circuit by removing connector 2 and 8 from oscillator circuit assembly A2 and check power supply voltages.
Power supply voltages return to +30 and -25 volts when power amplifier and/or oscillator circuits are isolated from power supply.	Load power supply by connecting a 300-ohm, 10-watt resistor (hp Stock No. 0815-0007) between the +30 and -25 volt supplies and check output voltages.
Power Supply output voltages drop when loaded with external load.	Check A1Q2, A1Q3, and Q1 and bias voltages shown in Figure 5-9. CAUTION DO NOT SHORT SUPPLY WHEN TAKING VOLTAGE READINGS.
Output voltage from +30 volt supply remains at 30 volts and -25 volt supply output drops when power supply is loaded with external load.	Check A1Q5 through A1Q7 and Q2 and bias voltages shown in Figure 5-9. CAUTION DO NOT SHORT SUPPLY WHEN TAKING VOLTAGE READINGS.
No output from +30 or -25 volt supplies with supplies isolated from Test Oscillator circuit.	Check A1CR1 and A1CR2. Check A1CR3 and A1CR4.
Power supply output voltages remain at +30 and -25 volts when loaded with external load.	Check power amplifier and/or oscillator circuits for conditions which cause an overload on power supply.
No output signal at 50-ohm and 600-ohm connectors with OUTPUT ATTENUATOR switch and FREQUENCY RANGE switch in any position (+30 and -25 volt power supplies operational).	Make the following checks with an Oscilloscope (hp Model 175A: 1. Check output signal (16 volts peak-to-peak minimum) from power amplifier circuit (connector 4) with AMPLITUDE control rotated fully cw. 2. Check input signal (approximately 10 volts peak-to-peak) to power amplifier circuit (connector 13) with AMPLITUDE control rotated fully cw. 3. Check output signal (approximately 10 volts peak-to-peak) from oscillator circuit (connector 16).

Table 5-6. Troubleshooting (Cont'd)

Indication	Action
No output signal at 50-ohm and 600-ohm connectors with OUTPUT ATTENUATOR switch in one or more positions.	Check OUTPUT ATTENUATOR switch components in inoperative positions (refer to Figure 5-8). For example, when no output signal is available with OUTPUT ATTENUATOR switch in the 1.0 volt (+10 db) position, check A3R5, A3R12, and A3R13.
No output on 600-ohm connector.	Check 550-ohm series resistor A3R1.
No output signal at 50-ohm and 600-ohm connectors with FREQUENCY RANGE switch in one or more positions.	Check FREQUENCY RANGE switch components connected to RC bridge circuit and peak detector circuit with switch placed in inoperative positions. For example, if X10 position is inoperative, check S1C1, S1C2, S1C7, S1R1, S1R2, S1R13, S1R14, and A2C7. Check FREQUENCY RANGE switch contacts.
Output signal amplitude not within specifications and/or distorted on all ranges.	Check power supply voltages (+30 and -25 volts). Check bias voltages in oscillator and power amplifier circuits. Check peak detector circuit (A2Q7 and A2CR5 - A2CR7) for proper operation (refer to waveform and voltages at A2TP1 and A2TP2 in Figure 5-8). Check A2CR5 for breakdown at 7 volts peak.
Output signal amplitude not within specifications and/or distorted on one or more ranges.	Check components connected to RC bridge circuit and peak detector circuit in affected ranges. For example, if output signal is low and/or distorted on X100 range, check S1C1, S1C2, S1C7, S1R3, S1R4, S1R15, and S1R16. (Check for improper error signal at A2TP1.)
Output meter does not track properly or reads consistently above or below all meter divisions.	Check A1CR8 through A1CR10.
Output meter indication drops to zero through portions of all frequency ranges.	Check tuner capacitor C1A, C1B, C1C for shorts.
Residual indication on output meter with AMPLITUDE control rotated fully ccw.	Check A1CR8 and A1CR9.
400 cps Meter Calibration adjustment A1R23 will not adjust for full-scale indication.	Check A1CR8, A1CR9, A1R23, A1Q8, A1Q9.
10 Mc Meter Calibration adjustment will not adjust properly.	Check A1C15.

b. Set Model 651A controls as follows:

FREQUENCY RANGE X1K
FREQUENCY Dial 1
OUTPUT ATTENUATOR . . . 3.0 v

c. Set Distortion Analyzer controls according to Paragraph 5-12 step d and measure distortion according to step e and vary Distortion Adjustment A2R17 for minimum distortion as read on Distortion Analyzer. Distortion should be less than 1% (40 db down).

NOTE

Typically, distortion will be -50 db down.

5-36. TROUBLESHOOTING.

5-37. Use the troubleshooting chart in Table 5-6, block diagram of Figure 4-1, and the schematics of Figures 5-8 and 5-9 to isolate a malfunction to a particular circuit. Troubleshoot your instrument only after it has been determined that the malfunction cannot be removed by performing the Adjustment and Calibration Procedures in Paragraph 5-14.

5-38. When a malfunction occurs, remove power from the Test Oscillator and visually inspect for broken wires, overheated or loose components, and similar conditions that could be a source of trouble. Use indications of malfunctions encountered in the Adjustment and Calibration procedures and Table 5-6 to select a starting point for troubleshooting.

CAUTION

DO NOT SHORT-CIRCUIT THE POWER SUPPLY WHEN MAKING ADJUSTMENTS AND VOLTAGE MEASUREMENTS.

5-39. OUTPUT METER CIRCUIT TROUBLESHOOTING.

5-40. When a malfunction has been isolated to the metering circuit, use the following signal substitution method to further isolate the trouble.

a. Disconnect connector 14 on A1 assembly.

b. Connect an external 6 v rms source to connector pin 14.

c. Take voltage readings at points shown on schematic diagram, Figure 5-8.

d. Check components A1Q8, A1Q9, A1CR8, A1CR9, A1CR10, and M1.

5-41. POWER AMPLIFIER TROUBLESHOOTING.

5-42. When a malfunction has been isolated to the power amplifier circuit, use the following signal substitution method to further isolate the trouble.

a. Disconnect connector 13 on A2 assembly.

b. Connect an external 8 - 10 volt peak-to-peak signal source to connector pin 13.

c. Take voltage readings shown on schematic diagram, Figure 5-8.

d. Check components A2Q8 through A2Q12 and associated circuit components.

5-43. OSCILLATOR AND PEAK DETECTOR TROUBLESHOOTING.

5-44. When a malfunction has been isolated to the oscillator and/or the peak detector circuit, use the following signal substitution method to further isolate the trouble.

a. Disconnect connector 10 on A2 assembly.

b. Connect an external 4-volt peak-to-peak source to connector pin 10.

c. Connect a 600-ohm resistor from pin 10 to ground for bias.

d. Take voltage readings shown on schematic diagram, Figure 5-8.

e. Observe waveforms shown at A2TP1 and A2TP2.

f. Check A2Q1 through A2Q7, A2CR1 through A2CR5, and associated circuit components.

5-45. Check RC Bridge components after it has been determined that the power amplifier and succeeding stages are operating properly.

5-46. REPAIR.

5-47. SERVICING ETCHED CIRCUIT BOARDS.

5-48. The two etched circuit boards, A1 and A2, used in the Model 651A are of the plated-through type which consist of a base board and conductor. This type of board can be soldered from either the conductor or component side of the board with equally good results.

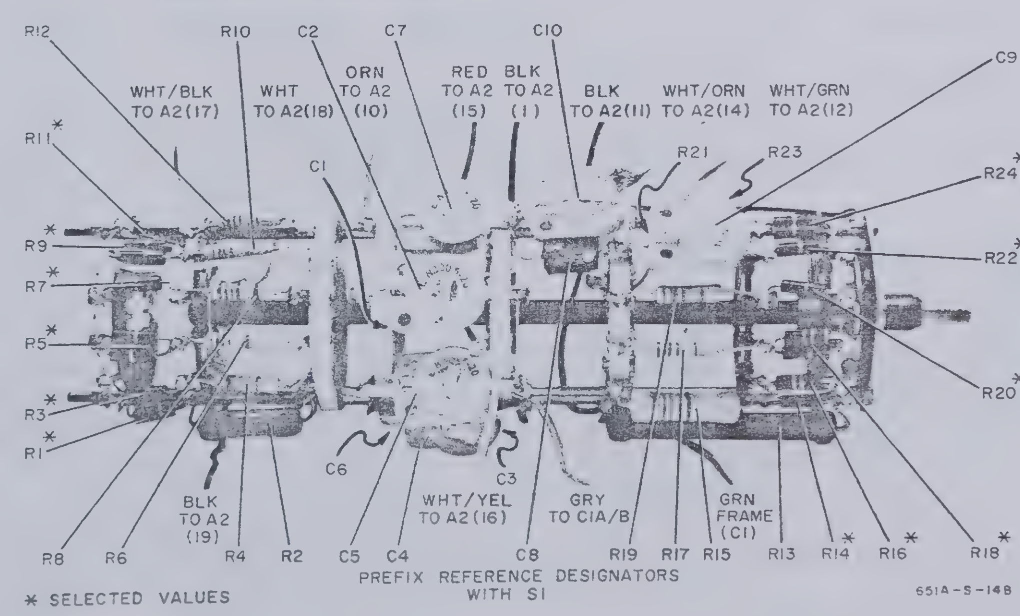


Figure 5-6. Range Switch Details

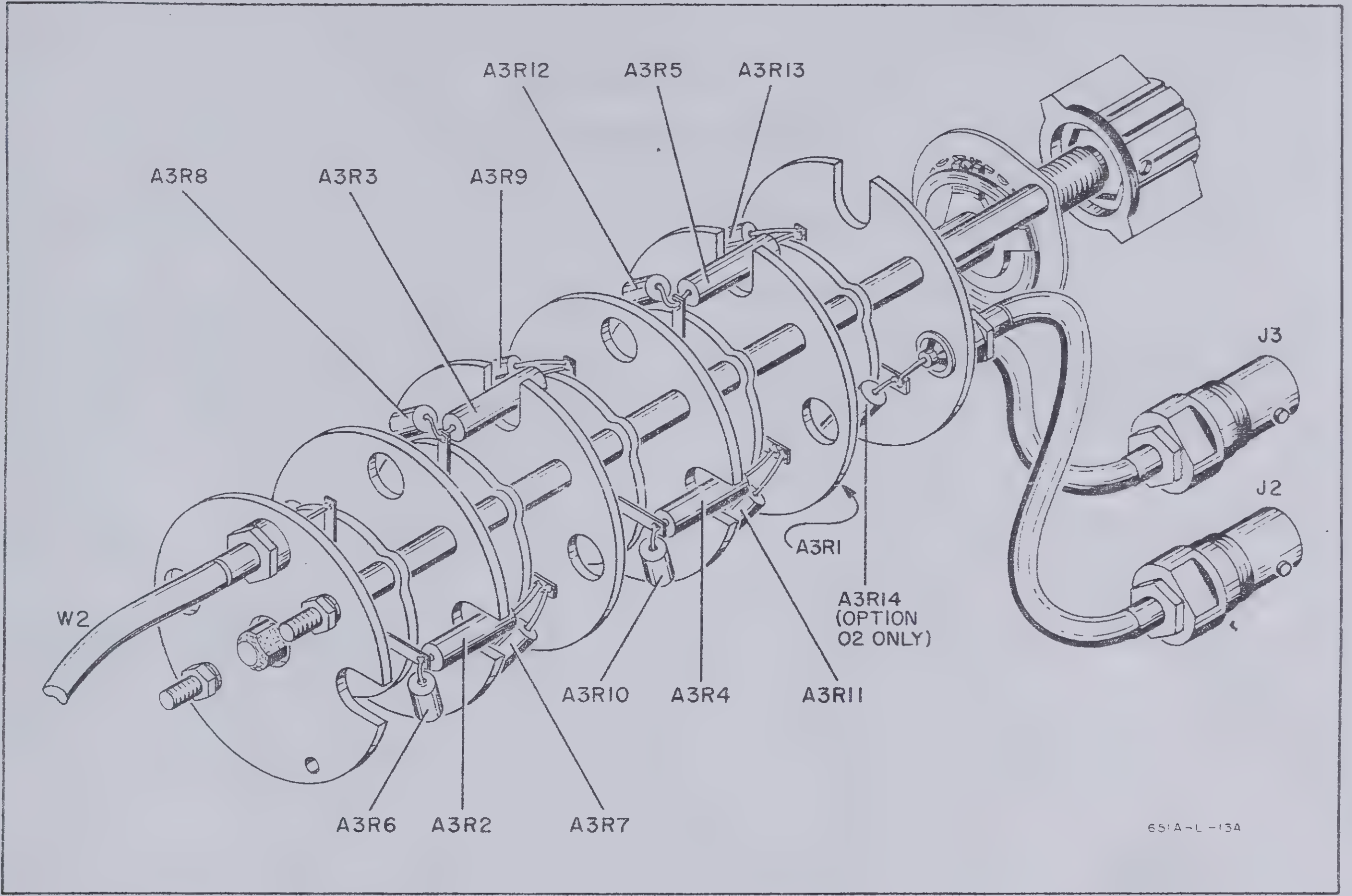


Figure 5-7. Output Attenuator Details

Observe the following suggestions when making repairs on this type of etched circuit board:

a. Avoid applying excessive heat when soldering on the circuit board.

b. To remove a damaged component, clip component leads near the component; then apply heat and remove each lead with a straight upward motion.

c. Use a special tool to remove components having multiple connections, such as potentiometers, transistors, etc. Refer to Table 5-1 for type of soldering tip required.

d. Use a toothpick to free eyelets of solder before installing a new component.

5-49. TRANSISTOR REPLACEMENT.

5-50. Transistors can be damaged by excessive heat. When replacing transistors on the Model 651A etched circuit boards, follow the instructions given in Paragraph 5-47.

5-51. RANGE SWITCH REPAIR.

5-52. Figure 5-6 gives parts location and wiring detail on the Model 651A FREQUENCY RANGE switch.

5-53. OUTPUT ATTENUATOR REPAIR.

5-54. Figure 5-7 gives parts location and cabling detail on the Model 651A OUTPUT ATTENUATOR switch.

5-55. TUNER ASSEMBLY REPLACEMENT.

5-56. When replacing the tuner assembly, make certain the tuner coupler and the frequency dial shaft are aligned to prevent binding in the FREQUENCY Dial and VERNIER adjustments. If necessary, remove the frequency dial knob, frequency dial, and loosen the tuner drive assembly (casting and spur gears) retaining screws to align tuner coupler and frequency dial shaft. Tighten retaining screws after tuner coupler and dial shaft are aligned.

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION.

6-2. This section contains information for ordering replacement parts. Table 6-1 lists parts in alpha-numerical order of their reference designators and indicates the description and hp stock number of each part, together with any applicable notes. Table 6-2 lists parts in alpha-numerical order of their hp stock number and provides the following information on each part:

a. Description of the part (see list of abbreviations below).

b. Typical manufacturer of the part in a five-digit code (see list of manufacturers in Appendix A).

c. Manufacturer's part number.

d. Total quantity used in the instrument (TQ column).

6-3. Miscellaneous parts are listed at the end of Table 6-1.

6-4. ORDERING INFORMATION.

6-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office (see Appendix B for list of office locations). Identify parts by their Hewlett-Packard stock numbers.

6-6. NON-LISTED PARTS.

6-7. To obtain a part that is not listed, include:

a. Instrument model number.

b. Instrument serial number.

c. Description of the part.

d. Function and location of the part.

REFERENCE DESIGNATORS

A = assembly
B = motor
C = capacitor
CR = diode
DL = delay line
DS = device signaling (lamp)
E = misc electronic part
F = fuse
FL = filter
J = jack
K = relay
L = inductor
M = meter
MP = mechanical part
P = plug
Q = transistor
R = resistor
RT = thermistor
S = switch
T = transformer
V = vacuum tube, neon bulb, photocell, etc.
W = cable
X = socket
XF = fuseholder
XDS = lampholder
Z = network

ABBREVIATIONS

a = amperes

bp = bandpass
bwo = backward wave oscillator

c = carbon
cer = ceramic
cmo = cabinet mount only
coef = coefficient
com = common
comp = composition
conn = connection
crt = cathode-ray tube

dep = deposited

EIA = Tubes or transistors meeting Electronic Industries' Association standards will normally result in instrument operating within specifications: tubes and transistors selected for best performance will be supplied if ordered by hp stock numbers.

elect = electrolytic
encap = encapsulated

f = farads
fxd = fixed

Ge = germanium
grd = ground (ed)
h = henries
Hg = mercury

impg = impregnated
incd = incandescent
ins = insulation (ed)

K = kilo = 1000

lin = linear taper
log = logarithmic taper

m = milli = 10^{-3}
M = megohms
ma = milliamperes
μ = micro = 10^{-6}
minat = miniature
mfgl = metal film on glass
mfr = manufacturer

mtg = mounting
my = mylar

NC = normally closed
Ne = neon

NO = normally open
NPO = negative positive zero (zero temperature coefficient)
nsr = not separately replaceable

obd = order by description

p = peak
pc = printed circuit board
pf = picofarads = 10^{-12} farads

pp = peak to peak
piv = peak inverse voltage

pos = position (s)
poly = polystyrene
pot = potentiometer

rect = rectifier

rot = rotary
rms = root-mean-square
rmo = rack mount only

s-b = slow-blow
Se = selenium
sect = section(s)
Si = silicon
sil = silver
sl = slide

td = time delay
TiO_2 = titanium dioxide

tog = toggle
tol = tolerance
trim = trimmer
twt = traveling wave tube

var = variable
w/ = with
W = watts
ww = wirewound
w/o = without

* = optimum value selected at factory, average value shown (part may be omitted)

Table 6-1. Reference Designation Index

Circuit Reference	Stock Number	Description	Note
A1	00651-66502	P. C. Board, power supply, includes: C2, C3, C5, C6 — Q5 thru Q9 C9 thru C16 — R1 thru R15 CR1 thru CR10 — R17 thru R20 Q2, Q3 — R22 thru R28	
A1C1		Not Assigned	
A1C2	0180-0045	C: fxd, elect, 20 μf +75% - 10%, 25 vdcw	
A1C3	0180-0149	C: fxd, elect al, 65 μf +100% -10%, 60 vdcw	
A1C4		Not Assigned	
A1C5	0180-0045	C: fxd, elect, 20 μf +75% -10%, 25 vdcw	
A1C6	0180-0149	C: fxd, elect al, 65 μf +100% -10%, 60 vdcw	
A1C7, A1C8		Not Assigned	
A1C9	0150-0084	C: fxd, cer, 0.1 μf +80% -20%, 50 vdcw	
A1C10	0180-0061	C: fxd, elect, 100 μf +100% -10%, 15 vdcw	
A1C11	0180-0062	C: fxd, elect, 300 μf +100% -10%, 6 vdcw	
A1C12	0180-0058	C: fxd, elect, 50 μf +100% -10%, 25 vdcw	
A1C13	0180-0058	C: fxd, elect, 50 μf +100% -10%, 25 vdcw	
A1C14	0180-0061	C: fxd, elect, 100 μf +100% -10%, 15 vdcw	
A1C15	0130-0018	C: var, cer, 1.5-7 pf	
A1C16	0180-0284	C: fxd, elect, 200 μf +75% -10%, 30 vdcw	
A1CR1 thru A1CR4	1901-0026	Diode, silicon	
A1CR5	1902-0045	Diode, breakdown, 7.2 v ±3%, 400 mw	
A1CR6, A1CR7	1901-0025	Diode, silicon	
A1CR8, A1CR9	1901-0027	Diode, silicon, HD5004 (selected)	
A1CR10	1901-0025	Diode, germanium	
A1Q1		Not Assigned	
A1Q2	1850-0107	Transistor, Ge 2N398A, PNP	
A1Q3	1850-0111	Transistor, Ge 2N404A, PNP	
A1Q4		Not Assigned	
A1Q5	1850-0107	Transistor, Ge 2N398A, PNP	
A1Q6 thru A1Q7	1850-0111	Transistor, Ge 2N404A, PNP	
A1Q8	1854-0218	Transistor: Si, 2N2716, NPN	
A1Q9	1854-0042	Transistor: Si, SM1570, NPN	
A1R1, A1R2	0686-7525	R: fxd, comp, 7.5 k ohms ±5%, 1/2 w	
A1R3	0687-3921	R: fxd, comp, 3.9 k ohms ±10%, 1/2 w	
A1R4	2100-0090	R: var, comp, lin, 2 k ohms ±30%, 1/3 w	
A1R5	0686-8225	R: fxd, comp, 8.2 k ohms ±5%, 1/2 w	
A1R6	0686-3025	R: fxd, comp, 3 k ohms ±5%, 1/2 w	
A1R7	0686-7525	R: fxd, comp, 7.5 k ohms ±5%, 1/2 w	
A1R8	0687-1531	R: fxd, comp, 15 k ohms ±10%, 1/2 w	
A1R9	0689-0915	R: fxd, 9.1 ohms ±5%, 1 w	
A1R10	0686-8215	R: fxd, comp, 820 ohms ±5%, 1/2 w	
A1R11	0686-4335	R: fxd, comp, 43 k ohms ±5%, 1/2 w	
A1R12	0757-0039	R: fxd, met flm, 5030 ohms ±1%, 1/2 w	
A1R13	0686-1015	R: fxd, comp, 100 ohms ±5%, 1/2 w	
A1R14	0757-1013	R: fxd, met flm, 6 k ohms ±1%, 1/2 w	

See introduction to this section

Table 6-1. Reference Designation Index (cont'd)

Circuit Reference	Stock Number	Description	Note
A1R15	0689-0915	R: fxd, comp, 9.1 ohms ±5%, 1 w	
A1R16		Not Assigned	
A1R17	0684-1001	R: fxd, comp, 10 ohms ±10%, 1/4 w	
A1R18, A1R19	0683-2025	R: fxd, comp, 2 k ohms ±5%, 1/4 w	
A1R20	0683-3935	R: fxd, comp, 39 k ohms ±5%, 1/4 w	
A1R21		Not Assigned	
A1R22	0683-1025	R: fxd, met flm, 1000 ohms ±5%, 1/4 w	
A1R23	2100-0282	R: var, ww, lin taper, 2 k ohms ±20%, 1 w	
A1R24	0687-1031	R: fxd, comp, 10 k ohms ±10%, 1/2 w	
A1R25	0684-1011	R: fxd, comp, 100 ohms ±10%, 1/4 w	
A1R26	0683-1535	R: fxd, comp, 15 k ohms ±5%, 1/4 w	
A1R27	0698-0026	R: fxd, met flm, 1.69 ohms ±1%, 1/2 w	
A1R28	0683-5115	R: fxd, comp, 510 ohms ±5%, 1/4 w	
A1R29	0766-0029	R: fxd, cer, 10 ohms ±2%, 3 w	
A2	00651-66501	P.C. Board, osc. ampl., includes:	
		C1 thru C22 R1 thru R27	
		CR1 thru CR7 R29 thru R31	
		Q1 thru Q12 R33 thru R44	
A2C1	0180-0061	C: fxd, elect, 100 μf +100% -10%, 15 vdcw	
A2C2	0180-0284	C: fxd, elect, 200 μf +75% -10%, 30 wvdc	
A2C3, A2C4	0150-0084	C: fxd, cer, 0.1 μf +80% -20%, 50 vdcw	
A2C5	0130-0018	C: var, cer, 1.5 - 7 pf	
A2C6	0180-0305	C: fxd, elect, 1000 μf +100% -10%, 2.5 vdcw	
A2C7	0180-0112	C: fxd, elect, 2000 μf, 1 vdcw	
A2C8	0180-0062	C: fxd, elect, 300 μf +100% -10%, 6 vdcw	
A2C9	0180-0076	C: fxd, elect, 20 μf, 25 vdcw	
A2C10	0150-0084	C: fxd, cer, 0.1 μf +80% -20%, 50 vdcw	
A2C11	0180-0060	C: fxd, elect, 200 μf +100% -10%, 3 vdcw	
A2C12	0180-0063	C: fxd, elect, 500 μf +100% -10%, 3 vdcw	
A2C13	0180-0039	C: fxd, elect, 100 μf, 12 vdcw	
A2C14	0130-0018	C: var, cer, 1.5 - 7 pf	
A2C15	0180-0062	C: fxd, elect, 300 μf +100% -10%, 6 vdcw	
A2C16, A2C17	0180-0101	C: fxd, elect, 1.8 μf ±10%, 35 vdcw	
A2C18	0180-0306	C: fxd, elect, 300 μf +100% -10%, 15 vdcw	
A2C19	0180-0307	C: fxd, elect, 500 μf +100% -10%, 15 vdcw	
A2C20	0180-0101	C: fxd, elect, 1.8 μf ±10%, 35 vdcw	
A2C21	0150-0042	C: fxd, TiO_2, 4.7 pf ±5%, 500 vdcw	
A2C22	0180-1756	C: fxd, elect, Al, 1200 μf, non-polar, 10 vdcw	
A2CR1	1902-0046	Diode, breakdown, 7.15 v ±10%	
A2CR2 thru A2CR4	1901-0025	Diode, silicon	
A2CR5	1902-0778	Diode, breakdown, 7.87 v ±2%	
A2CR6, A2CR7	1910-0016	Diode, germanium	
A2Q1	1855-0004	Transistor: Uni-polar, Si, U112	
A2Q2	1854-0042	Transistor: Si, SM1570, NPN	
A2Q3	1853-0046	Transistor: 2N3250	
A2Q4, A2Q5	1854-0053	Transistor: Si, 2N2218, NPN	
	1200-0080	Washer - Insulator	
	1205-0007	Nut - Heat Sink	
	1205-0008	Body - Heat Sink	

\# See introduction to this section

Table 6-1. Reference Designation Index (cont'd)

Circuit Reference	ⓗ Stock Number	Description	Note
A2Q6	1853-0006	Transistor: 2N3134	
A2Q7	1854-0044	Transistor: Si, 2N2716, NPN	
A2Q8	1854-0042	Transistor: Si, SM1570, NPN	
A2Q9	1853-0007	Transistor: 2N3251	
A2Q10, A2Q11	1854-0053	Transistor: Si, 2N2218, NPN	
	1200-0080	Washer - Insulator	
	1205-0007	Nut - Heat Sink	
	1205-0008	Body - Heat Sink	
A2Q12	1853-0006	Transistor: 2N3134	
	1200-0080	Washer - Insulator	
	1205-0007	Nut - Heat Sink	
	1205-0008	Body - Heat Sink	
A2R1	0687-1021	R: fxd, comp, 1 k ohm ±10%, 1/2 w	
A2R2	0683-6225	R: fxd, comp, 6.2 k ohms ±5%, 1/4 w	
A2R3	0683-4335	R: fxd, comp, 43 k ohms ±5%, 1/4 w	
A2R4	0683-1025	R: fxd, comp, 1000 ohms ±5%, 1/4 w	
A2R5	0684-1221	R: fxd, comp, 1.2 k ohms ±10%, 1/4 w	
A2R6	0683-9105	R: fxd, comp, 91 ohms ±5%, 1/4 w	
A2R7	0683-2005	R: fxd, comp, 20 ohms ±5%, 1/4 w	
A2R8, A2R9	0686-1025	R: fxd, comp, 1 k ohm ±5%, 1/2 w	
A2R10	0693-8211	R: fxd, comp, 820 ohms ±10%, 2 w	
A2R11, A2R12	0686-1305	R: fxd, comp, 13 ohms ±5%, 1/2 w	
A2R13	0687-1001	R: fxd, comp, 10 ohms ±10%, 1/2 w	
A2R14	0757-0824	R: fxd, met flm, 2 k ohms ±1%, 1/2 w	
A2R15	0757-0197	R: fxd, met flm, 1.5 k ohms ±1%, 1/2 w	
A2R16	0757-1090	R: fxd, met flm, 261 ohms ±1%, 1/2 w	
A2R17	2100-0108	R: var, comp, lin, 100 ohms ±30%	
A2R18	0687-1011	R: fxd, comp, 100 ohms ±10%, 1/2 w	
A2R19	0686-2035	R: fxd, comp, 20 k ohms ±5%, 1/2 w	
A2R20	0686-0275	R: fxd, comp, 2.7 ohms ±5%, 1/2 w	
A2R21	0687-1031	R: fxd, comp, 10 k ohms ±10%, 1/2 w	
A2R22	0757-0824	R: fxd, met flm, 2 k ohms ±1%, 1/2 w	
A2R23	0687-4701	R: fxd, comp, 47 ohms ±10%, 1/2 w	
A2R24	0686-3925	R: fxd, comp, 3.9 k ohms ±5%, 1/2 w	
A2R25	0757-1011	R: fxd, met flm, 18 k ohms ±1%, 1/2 w	
A2R26	0687-1001	R: fxd, comp, 10 ohms ±10%, 1/2 w	
A2R27	0683-0275	R: fxd, comp, 2.7 ohms ±5%, 1/4 w	
A2R28		Not Assigned	
A2R29	0687-1521	R: fxd, comp, 1.5 k ohms ±10%, 1/2 w	
A2R30	0686-3935	R: fxd, comp, 39 k ohms ±5%, 1/2 w	
A2R31	0686-8235	R: fxd, comp, 82 k ohms ±5%, 1/2 w	
A2R32		Not Assigned	
A2R33	0687-1511	R: fxd, comp, 150 ohms ±10%, 1/2 w	
A2R34	0686-2025	R: fxd, comp, 2 k ohms ±5%, 1/2 w	
A2R35	0689-4315	R: fxd, comp, 430 ohms ±5%, 1 w	
A2R36	0693-6811	R: fxd, comp, 680 ohms ±10%, 2 w	
A2R37, A2R38	0683-0275	R: fxd, comp, 2.7 ohms ±5%, 1/4 w	
A2R39, A2R40	0757-1012	R: fxd, met flm, 100 ohms ±0.25%, 1/2 w	

\# See introduction to this section

Table 6-1. Reference Designation Index (cont'd)

Circuit Reference	Stock Number	Description	Note
A2R41	0683-3615	R: fxd, comp, 360 ohms ±5%, 1/4 w	
A2R42, A2R43	0683-1025	R: fxd, comp, 1000 ohms ±5%, 1/4 w	
A2R44	0683-0275	R: fxd, comp, 2.7 ohms ±5%, 1/4 w	
A3	00651-63402	Attenuator Assembly for standard instrument and Option 01 only, includes: R1 thru R13	
	00651-6340	Attenuator Assembly for Option 02 only, includes: R1 thru R14	
A3R1	0757-1016	R: fxd, met flm, 550 ohms ±0.25%, 1/2 w	
A3R2, A3R3	0757-1009	R: fxd, met flm, 790 ohms ±0.25%, 1/2 w	
A3R4	0757-1008	R: fxd, met flm, 247.5 ohms ±0.25%, 1/2 w	
A3R5	0757-1006	R: fxd, met flm, 71.15 ohms ±0.25%, 1/2 w	
A3R6 thru A3R9	0757-1004	R: fxd, met flm, 53.27 ohms ±0.25%, 1/2 w	
A3R10, A3R11	0757-1005	R: fxd, met flm, 61.11 ohms ±0.25%, 1/2 w	
A3R12, A3R13	0757-1007	R: fxd, met flm, 96.25 ohms ±0.25%, 1/2 w	
A3R14	0757-1025	R: fxd, met flm, 25 ohms ±1%, 1/4 w	Option 02 only
A3S2	3100-0884	Switch, attenuator	
C1A thru C1C	0121-0018	C: var, air, 3 sections, 0-600 pf	
C2	0150-0014	C: fxd, cer, 5000 pf, 500 vdcw	
C3, C4	0150-0005	C: fxd, feed thru, cer, 1000 pf ±25%, 500 vdcw	
C5, C6	0180-0047	C: fxd, elect. 500 µf, 75 vdcw	
C7	0150-0014	C: fxd, cer, 5000 pf, 500 vdcw	
DS1	2140-0015	Lamp, glow neon, NE-2H bulb T2 (pilot light)	
	5040-0234	Pilot Light - jewel	
	5040-0235	Pilot Light - base	
F1	2110-0019	Fuse, cartridge, 0.4 amp, slow-blow	
J1	1251-0148	Connector, power, receptacle, 3 pin male	
J2, J3	00651-61601	Cable Assembly, output	
L1 thru L4	9140-0029	Coil, R.F., 100 mh	
M1	1120-0350	Meter, 50 ohm dbm scale, standard instrument only	
	1120-0360	Meter, 600 ohm dbm scale, Option 01 only	
	1120-0370	Meter, 75 ohm dbm scale, Option 02 only	
P1, P2	8120-0078	Cable Assembly, power, 7.5 feet long	
Q1	1850-0098	Transistor, PNP, germanium	
	1200-0043	Insulator - Transistor	
Q2	1850-0098	Transistor, PNP, germanium	
	1200-0043	Insulator - Transistor	
R1	0684-3331	R: fxd, comp, 33 k ohms ±10%, 1/4 w	
R2	2100-0732	R: var, molded comp, linear taper, 500 ohms ±10% 2.25 w	
S1	00651-61901	Range Switch Assembly, includes: C1 - C10, R1 - R24	
	3100-0860	Range Switch	
S1C1		C: fxd, molded mica, 75 pf ±5%, 500 vdcw	
S1C2	0130-0006	C: var, cer, 5-20 pf	
S1C3	0140-0032	C: fxd, molded mica, 47 pf ±10%, 500 vdcw	
S1C4	0130-0001	C: var, cer, 7-45 pf	
S1C5	0130-0006	C: var, cer, 5-20 pf	
S1C6	0160-0987	C: fxd, dipped mica, 12 pf ±5%, 500 vdcw	
S1C7	0130-0006	C: var, cer, 5-20 pf	

See introduction to this section

Table 6-1. Reference Designation Index (cont'd)

Circuit Reference	ℏp Stock Number	Description	Note
S1C8	0140-0001	C: fxd, molded mica, 5 pf ±20%, 500 vdcw	
S1C9, S1C10	0130-0003	C: var, cer, 1.5-7 pf	
S1R1	0686-5645	R: fxd, comp, 560 k ohms ±5%, 1/2 w	
S1R2	0730-0145	R: fxd, dep c flm, 12M ohms ±1%, 1 w	
S1R3	0686-3935	R: fxd, comp, 39 k ohms ±5%, 1/2 w	
S1R4	0757-0983	R: fxd, met flm, 1.23M ohms ±1%, 1/2 w	
S1R5	0686-3925	R: fxd, comp, 3.9 k ohms ±5%, 1/2 w	
S1R6	0757-0981	R: fxd, met flm, 123 k ohms ±1%, 1/2 w	
S1R7	0686-4315	R: fxd, comp, 430 ohms ±5%, 1/2 w	
S1R8	0757-0042	R: fxd, met flm, 12.3 k ohms ±1%, 1/2 w	
S1R9	0686-1305	R: fxd, comp, 13 ohms ±5%, 1/2 w	
S1R10	0757-0821	R: fxd, met flm, 1.21 k ohms ±1%, 1/2 w	
S1R11	0686-2005	R: fxd, comp, 20 ohms ±5%, 1/2 w	
S1R12	0757-0198	R: fxd, met flm, 100 ohms ±1%, 1/2 w	
S1R13	0733-0006	R: fxd, dep c flm, 24.5 M ohms ±1%, 2 w	
S1R14	0686-1855	R: fxd, comp, 1.8 megohms ±5%, 1/2 w	
S1R15	0757-1017	R: fxd, met flm, 2.45 M ohms ±1%, 1/2 w	
S1R16	0686-1245	R: fxd, comp, 120 k ohms ±5%, 1/2 w	
S1R17	0757-0982	R: fxd, met flm, 245 k ohms ±1%, 1/2 w	
S1R18	0686-1235	R: fxd, comp, 12 k ohms ±5%, 1/2 w	
S1R19	0757-1014	R: fxd, met flm, 24.5 k ohms ±1%, 1/2 w	
S1R20	0686-1125	R: fxd, comp, 1100 ohms ±5%, 1/2 w	
S1R21	0757-0038	R: fxd, met flm, 2.51 k ohms ±1%, 1/2 w	
S1R22	0686-1115	R: fxd, comp, 110 ohms ±5%, 1/2 w	
S1R23	0757-0980	R: fxd, met flm, 225 ohms ±1%, 1/2 w	
S1R24	0686-3005	R: fxd, comp, 30 ohms ±5%, 1/2 w	
S2	3101-0036	Switch, toggle, SPST	
S3	3101-0033	Switch, slide, DPDT, 115/230 volts	
T1	9100-0294	Transformer, power	
W1	8120-0078	Cable Assembly, power, 7.5 feet long	
W2	00651-61602	Cable Assembly, input	
		MISCELLANEOUS	
	61B-40D-4	Plate - Frequency Dial	
	0370-0025	Knob, Vernier	
	0370-0026	Knob, Amplitude	
	0370-0160	Knob, Dial	
	0370-0112	Knob, Bar	
	1200-0043	Insulator, Transistor, Mtg.	
	1200-0080	Washer - Insulator for 10-32 screw	
	1200-0081	Insulator, Bushing Nylon	
	1205-0007	Nut - Heat Dissipator	
	1205-0008	Body - Heat Dissipator	
	1400-0084	Fuseholder, Post Type, extractor	
	1490-0030	Stand, Tilt	
	1500-0002	Yoke, Coupler, Flexible	
	5000-0051	Strip, Cabinet Trim	
	5000-0637	Spring, Thrust	

See introduction to this section

Table 6-1. Reference Designation Index (cont'd)

Circuit Reference	ℏ Stock Number	Description	Note
		MISCELLANEOUS (cont'd)	
	5000-0732	Cover, Side Rear, 5 x 11 FM	
	5000-0733	Cover, Side Front, 5 x 11 FM	
	5020-0348	Shaft	
	5020-0630	Hub - Dial	
	5020-0639	Casting - Cap, Drive Assembly	
	5020-0641	Shaft- Spur Gear	
	5040-0212	Insulator, Coupler	
	5040-0234	Pilot Light - Jewel	
	5040-0235	Pilot Light - Base	
	5040-0607	Disc, Assembly, Vernier Drive	
	5040-0642	Indicator - Dial	
	5040-0631	Bracket - Cap. Mount	
	5060-0020	Gear - Assembly	
	5060-0021	Gear - Assembly	
	5060-0731	Frame Assembly - 5 x 11 FM	
	5060-0739	Cover - Assembly - Top, 11 LFM	
	5060-0751	Cover - Assembly - Bottom, 11 LFM	
	5060-0222	Handle Assembly, side	
	5060-0766	Retainer, 5H Handle Assembly	
	5060-0767	Foot, Cabinet Assembly FM	
	9211-0248	Carton - Corrugated	
	9223-0040	Foam - Polyethylene	
	00651-00101	Deck - Main	
	00651-00102	Plate - Capacitor	
	00651-00201	Panel - Front; standard instrument only	
	00651-00202	Panel - Rear	
	00651-00203	Panel - Front, Option 01 only	
	00651-00204	Panel - Front, Option 02 only	
	00651-01202	Bracket - Switch	
	00651-04001	Dial	
	00651-04101	Plate - Cover	
	00651-90001	Manual, Operating and Service	

See introduction to this section

Table 6-2. Replaceable Parts

# Stock No	Description	Mfr.	Mfr. Part No.	TQ	
61B-40D-4	Plate - Freq. Dial	28480	61B-40D-4	1	
0121-0018	C: var, 3 sections, air, 0-600 pf	28480	0121-0018	1	
0130-0001	C: var, cer, 7-45 pf	72982	503000-D2P0-33R	1	
0130-0003	C: var, cer, 1.5-7 pf	71590	DA-825	1	
0130-0006	C: var, cer, 5-20 pf	71590	DA-825	1	
0130-0018	C: var, cer, 1.5-7 pf	72982	557-019-C0P0-10R	3	
0140-0001	C: fxd, molded mica, 5 pf ±20%, 500 vdcw	14655	RCM15C050M	1	
0140-0032	C: fxd, molded mica, 47 pf ±10%, 500 vdcw	14655	RCM15E470K	1	
0140-0040	C: fxd, molded mica, 75 pf ±5%, 500 vdcw	04062	RCM15E750J	1	
0150-0005	C: fxd, feed thru, cer, 1000 pf ±25%, 500 vdcw	04222	CFS-1	1	
0150-0014	C: fxd, cer, 5000 pf, 500 vdcw	04222	D1-4	1	
0150-0042	C: fxd, TiO_2, 4.7 pf ±5%, 500 vdcw	28480	JM	1	
0150-0084	C: fxd, cer, 0.1 μf +80% -20%, 50 vdcw	72982	845-222-Y5V0 1042	1	
0160-0987	C: fxd, dipped mica, 12 pf ±5%, 500 vdcw	00853	RDM15C120J5C	1	
0180-0039	C: fxd, elect, 100μf, 12 vdcw	56289	30D154A1	1	
0180-0045	C: fxd, elect, 20 μf +75% -10%, 25 vdcw	56289	30D206-GO-25DB-6M1		
0180-0047	C: fxd, elect, 500μf, 75 vdcw	56289	D32443	1	
0180-0058	C: fxd, elect, 50μf +100% -10%, 25 vdcw	56289	D28110	1	
0180-0060	C: fxd, elect, 200 μf +100% -10%, 3 vdcw	56289	30D207G00 3DC4	1	
0180-0061	C: fxd, elect, 100μf +100% -10%, 15 vdcw	56289	30D107GO 15DD4	1	
0180-0062	C: fxd, elect, 300 μf +100% -10%, 6 vdcw	56289	30D-137GO 06DH4	2	
0180-0063	C: fxd, elect, 500μf +100% -10%, 3 vdcw	56289	D32530	1	
0180-0076	C: fxd, elect, 20μf, 25 vdcw	56289	40D-181-A2	1	
0180-0101	C: fxd, elect, 1.8 μf ±10%, 35 vdcw	56289	150D185x9035 B2	2	
0180-0112	C: fxd, elect, 2000μf, 1 vdcw	56289	D33239	1	
0180-0149	C: fxd, elect, 65 μf +100% -10%, 60 vdcw	56289	30D	1	
0180-0284	C: fxd, elect, 200μf +75% -10%, 30 vdcw	56289	D38559	1	
0180-0305	C: fxd, elect, 1000μf +100% -10%, 2.5 vdcw	56289	34D108H2R5 FJ4	1	
0180-0306	C: fxd, elect, 300μf +100% -10%, 15 vdcw	56289	34D307H015 FJ4	1	
0180-0307	C: fxd, elect, 500μf +100% -10%, 15 vdcw	56289	34D507H015 GJ4	1	
0180-1756	C: fxd, elect, 1200 μf, non-polar, 10 vdcw	56289	34D	1	
0340-0060	Insulator, teflon	98291	FT-E-15	1	
0370-0025	Knob, Vernier	28480	0370-0025	1	
0370-0026	Knob, Amplitude	28480	0370-0026	1	
0370-0160	Knob, Dial	28480	0370-0038	1	
0370-0112	Knob, Bar	28480	0370-0112	2	
0683-0275	R: fxd, comp, 2.7 ohms ±5%, 1/4 w	01121	CB27G5	3	
0683-1025	R: fxd, comp, 1000 ohms ±5%, 1/4 w	01121	CB1025	2	
0683-1535	R: fxd, comp, 15 k ohms ±5%, 1/4 w	01121	CB1535	1	
0683-2005	R: fxd, comp, 20 ohms ±5%, 1/4 w	01121	CB1805	1	
0683-2025	R: fxd, comp, 2 k ohms ±5%, 1/4 w	01121	CB2025	1	
0683-3615	R: fxd, comp, 360 ohms ±5%, 1/4 w	01121	CB3615	1	
0683-3935	R: fxd, comp, 39 k ohms ±5%, 1/4 w	01121	CB3935	1	

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Table 6-2. Replaceable Parts (cont'd)

ⓗⓟ Stock No.	Description	Mfr.	Mfr. Part No.	TQ	
0683-4335	R: fxd, comp, 43 k ohms ±5%, 1/4 w	01121	CB4335	1	
0683-5115	R: fxd, comp, 510 ohms ±5%, 1/4 w	01121	CB5115	1	
0683-6225	R: fxd, comp, 6.2 k ohms ±5%, 1/4 w	01121	CB6225	1	
0683-1025	R: fxd, comp, 1K ohms ±5%, 1/4 w	01121	CB7505	1	
0683-9105	R: fxd, comp, 91 ohms ±5%, 1/4 w	01121	CB9105	1	
0684-1001	R: fxd, comp, 10 ohms ±10%, 1/4 w	01121	CB1001	1	
0684-1011	R: fxd, comp, 100 ohms ±10%, 1/4 w	01121	CB1011	1	
0684-1221	R: fxd, comp, 1.2 k ohms ±10%, 1/4 w	01121	CB1221	1	
0684-3331	R: fxd, comp, 33 k ohms ±10%, 1/4 w	01121	CB3331	1	
0686-0275	R: fxd, comp, 2.7 ohms ±5%, 1/2 w	01121	EB0275	1	
0686-1015	R: fxd, comp, 100 ohms ±5%, 1/2 w	01121	EB1015	1	
0686-1025	R: fxd, comp, 1 k ohm ±5%, 1/2 w	01121	EB1025	1	
0686-1115	R: fxd, comp, 1100 ohms ±5%, 1/2 w	01121	EB1115	1	
0686-1125	R: fxd, comp, 1100 ohms ±5%, 1/2 w	01121	EB1125	1	
0686-1235	R: fxd, comp, 12 k ohms ±5%, 1/2 w	01121	EB1235	1	
0686-1245	R: fxd, comp, 120 k ohms ±5%, 1/2 w	01121	EB1245	1	
0686-1305	R: fxd, comp, 13 ohms ±5%, 1/2 w	01121	EB1305	2	
0686-1855	R: fxd, comp, 1.8 megohms ±5%, 1/2 w	01121	EB1855	1	
0686-2005	R: fxd, comp, 20 ohms ±5%, 1/2 w	01121	EB2005	1	
0686-2025	R: fxd, comp, 2 k ohms ±5%, 1/2 w	01121	EB2025	1	
0686-2035	R: fxd, comp, 20 k ohms ±5%, 1/2 w	01121	EB2035	1	
0686-3005	R: fxd, comp, 30 ohms ±5%, 1/2 w	01121	EB3005	1	
0686-3025	R: fxd, comp, 3 k ohms ±5%, 1/2 w	01121	EB3025	1	
0686-3925	R: fxd, comp, 3.9 k ohms ±5%, 1/2 w	01121	EB3925	2	
0686-3935	R: fxd, comp, 39 k ohms ±5%, 1/2 w	01121	EB3935	2	
0686-4315	R: fxd, comp, 430 ohms ±5%, 1/2 w	01121	EB4312	1	
0686-4335	R: fxd, comp, 43 k ohms ±5%, 1/2 w	01121	EB4335	1	
0686-5645	R: fxd, comp, 560 k ohms ±5%, 1/2 w	01121	EB5645	1	
0686-7525	R: fxd, comp, 7.5 k ohms ±5%, 1/2 w	01121	EB7525	2	
0686-8215	R: fxd, comp, 820 ohms ±5%, 1/2 w	01121	EB8215	1	
0686-8225	R: fxd, comp, 8.2 k ohms ±5%, 1/2 w	01121	EB8225	1	
0686-8235	R: fxd, comp, 82 k ohms ±5%, 1/2 w	01121	EB8235	1	
0687-1001	R: fxd, comp, 10 ohms ±10%, 1/2 w	01121	EB1001	2	
0687-1011	R: fxd, comp, 100 ohms ± 10%, 1/2 w	01121	EB1011	1	
0687-1021	R: fxd, comp, 1 k ohm ±10%, 1/2 w	01121	EB1021	1	
0687-1031	R: fxd, comp, 10 k ohms ±10%, 1/2 w	01121	EB1031	2	
0687-1511	R: fxd, comp, 150 ohms ±10%, 1/2 w	01121	EB1511	1	
0687-1521	R: fxd, comp, 1.5 k ohms ±10%, 1/2 w	01121	EB1521	1	
0687-1531	R: fxd, comp, 15 k ohms ±10%, 1/2 w	01121	EB1531	1	
0687-3921	R: fxd, comp, 3.9 k ohms ±10%, 1/2 w	01121	EB3921	1	
0687-4701	R: fxd, comp, 47 ohms ±10%, 1/2 w	01121	EB4315	1	
0689-0915	R: fxd, comp, 9.1 ohms ±5%, 1 w	01121	GB91G5	1	
0689-4315	R: fxd, comp, 430 ohms ±5%, 1 w	01121	EB4315	1	
0693-6811	R: fxd, comp, 680 ohms ±10%, 2 w	01121	HB6811	1	
0693-8211	R: fxd, comp, 820 ohms ±10%, 2 w	01121	HB8211	1	
0698-0026	R: fxd, met flm, 1.69 ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0730-0145	R: fxd, dep c flm, 12 M ohms ±1%, 1 w	19701	MF7CT-0	1	
0733-0006	R: fxd, dep c flm, 24.5 M ohms ±1%, 2 w	19701	DC-2	1	
0757-0038	R: fxd, met flm, 2.51 k ohms ±1%, 1/2 w	19701	CECT-0	1	
0757-0039	R: fxd, met flm, 5030 ohms ±1%, 1/2 w	07115	N20	1	
0757-0042	R: fxd, met flm, 12.3 k ohms ±1%, 1/2 w	19701	CECT-0	1	
0757-0197	R: fxd, met flm, 1.5 k ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0757-0198	R: fxd, met flm, 100 ohms ±1%, 1/2 w	19701	MF7CT-0	1	

See introduction to this section

Table 6-2. Replaceable Parts (cont'd)

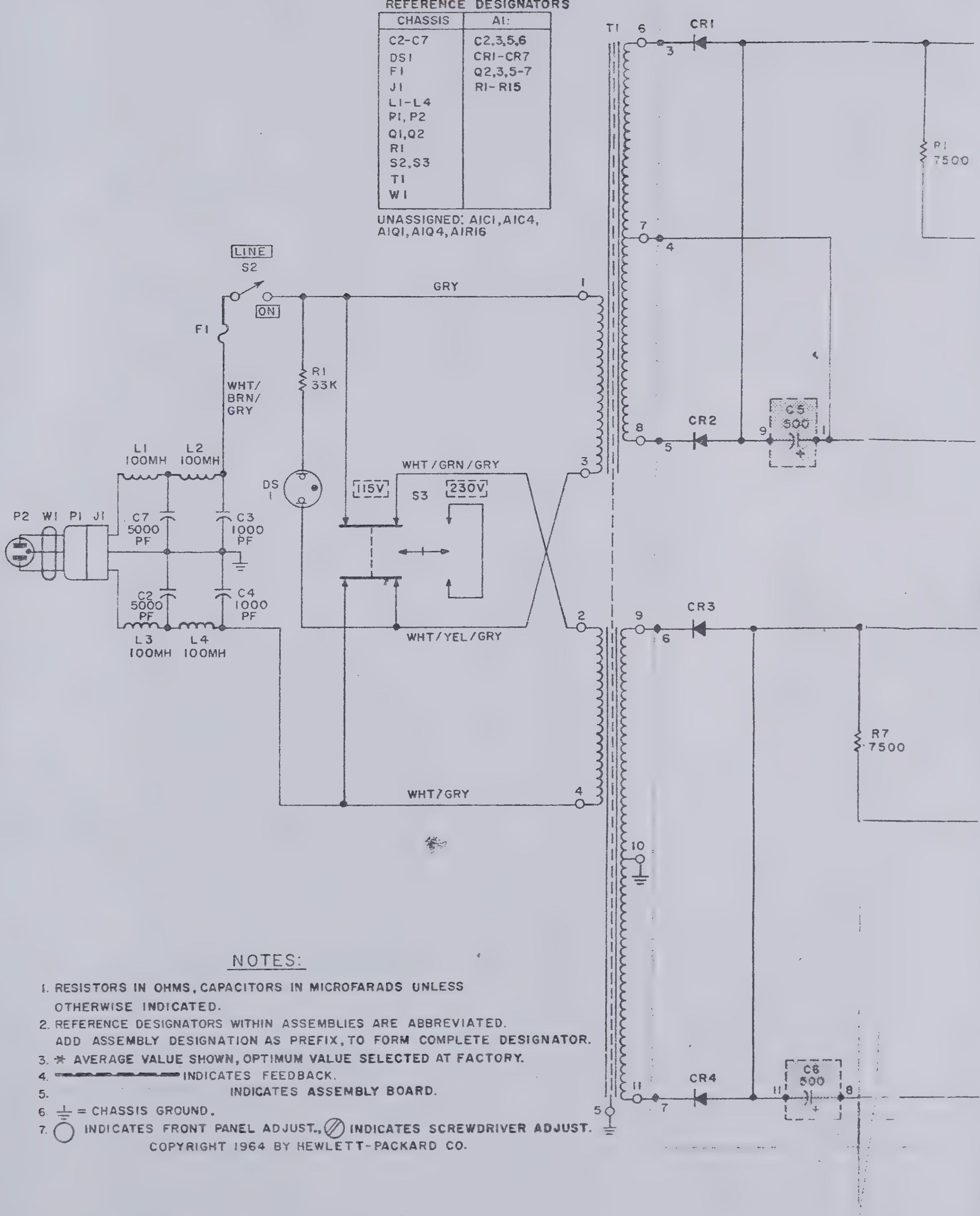
℗ Stock No.	Description	Mfr.	Mfr. Part No.	TQ	
0757-0821	R: fxd, met flm, 1.21 k ohms ±1%, 1/2 w	19701	CECT-0	1	
0757-0824	R: fxd, met flm, 2 k ohms ±1%, 1/2 w	19701	CECT-0	2	
0757-0980	R: fxd, met flm, 225 ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0757-0981	R: fxd, met flm, 123 k ohms ±1%, 1/2 w	19701	CECT-0	1	
0757-0982	R: fxd, met flm, 245 k ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0757-0983	R: fxd, met flm, 1.23 M ohms ±1%, 1/2 w	19701	CECT-0	1	
0757-1004	R: fxd, met flm, 53.27 ohms ±0.25%, 1/2 w	19701	MF7CT-0	1	
0757-1005	R: fxd, met flm, 61.11 ohms ±0.25%, 1/2 w	19701	MF7CT-0	1	
0757-1006	R: fxd, met flm, 71.15 ohms ±0.25%, 1/2 w	19701	MF7CT-0	1	
0757-1007	R: fxd, met flm, 96.25 ohms ±0.25%, 1/2 w	19701	MF7CT-0	1	
0757-1008	R: fxd, met flm, 247.5 ohms ±0.25%, 1/2 w	19701	MF7CT-0	1	
0757-1009	R: fxd, met flm, 790 ohms ±0.25%, 1/2 w	19701	MF7CT-0	1	
0757-1011	R: fxd, met flm, 18 k ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0757-1012	R: fxd, met flm, 100 ohms ±0.25%, 1/2 w	19701	MF7CT-0	1	
0757-1013	R: fxd, met flm, 6 k ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0757-1014	R: fxd, met flm, 24.5 k ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0757-1016	R: fxd, met flm, 550 ohms ±0.25%, 1/2 w	19701	MF7CT-0	1	
0757-1017	R: fxd, met flm, 2.45 M ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0757-1025	R: fxd, met flm, 25 ohms ±1%, 1/4 w	75042	CEBT-0	1	
0757-1090	R: fxd, met flm, 270 ohms ±1%, 1/2 w	19701	MF7CT-0	1	
0766-0029	R: fxd, cer, ±2%, 3 w			1	
1120-0350	Meter, 50 ohms dbm scale	65092	1931	1	
1200-0043	Insulator, transistor, mtg	28480	1200-0043	3	
1200-0080	Washer, insulating for 10-32 screw	28480	1200-0080	5	
1200-0081	Insulator, bushing, nylon	26365	974 Special	1	
1205-0007	Nut, Heat Dissipator	05046	50M-S-3487 No. 1	5	
1205-0008	Body, Heat Dissipator	05046	50M-S-3487 No. 2	5	
1205-0018	Heat sink, semiconductor heat dissipator	05820	NF-203	1	
1251-0148	Connector, power, receptacle, 3 pin male	82389	AC3G	1	
1400-0084	Holder, fuse, extractor, post type	75915	342014	1	
1490-0030	Stand, tilt	91260		1	
1500-0002	Yoke, coupler, for 1/4 inch shaft	76487	Single yoke portion of 39006 coupler	1	
1850-0098	Transistor, PNP, germanium	28480	1850-0098	2	
1850-0107	Transistor, Ge, 2N398A, PNP	01295	2N398A	1	
1850-0111	Transistor, Ge, 2N404A, PNP	01295	2N404A	1	
1853-0006	Transistor, 2N3134	28480	1853-0006	2	
1853-0007	Transistor, 2N3251	04713	2N3251	1	
1853-0046	Transistor, 2N3250	04713	2N3250	1	
1854-0013	Transistor, Si, 2N2218, NPN	04713	2N2218A	2	
1854-0042	Transistor, Si, SM1570, NPN	28480	1854-0042	3	
1854-0053	Transistor, Ge, 2N2218, NPN	04713	2N2218	1	
1854-0218	Transistor, Si, 2N3393 NPN	24446	2N3393	2	
1855-0004	Transistor, Uni-polar, Si, U112	28480	1855-0004	1	
1901-0025	Diode, silicon	28480	1901-0025	1	
1901-0026	Diode, silicon	01841		1	
1901-0027	Diode, silicon	73293	HD5004	1	
1902-0045	Diode, breakdown, 7.2 v ±3%, 400 mw	04713	SZ10939-144	1	
1902-0046	Diode, breakdown, 7.15 v ±10%	04713	SZ10939-139	1	
1902-0778	Diode, breakdown, 7.87 v ±2%	04713		1	

See introduction to this section

Table 6-2. Replaceable Parts (cont'd)

Stock No.	Description	Mfr.	Mfr. Part No.	TQ	
1910-0016	Diode, germanium	11711	GD150	2	
2100-0090	R: var, comp, lin, 2 k ohms ±20%, 1/3 w	11236	UPE 70 (SPL)	1	
2100-0108	R: var, comp, lin, 100 ohms ±30%	11236	UPE 70 (SPL)	1	
2100-0282	R: var, ww, lin taper, 2 k ohms ±20%, 1 w	11236	Series 110	1	
2100-0732	R: var, molded comp, linear taper, 500 ohms ±10%, 2.25 w	01121	Type J	1	
2110-0019	Fuse, cartridge, 0.4 amp, slow-blow	75915	313J 400	1	
2140-0015	Lamp, glow, neon, NE-2H bulb, T2 (pilot light)	24455		1	
3100-0859	Switch, attenuator	76854		1	
3101-0033	Switch, slide, DPDT, 115/230 v	42190	4633	1	
3101-0036	Switch, toggle, SPST	88140	8280K16	1	
5000-0051	Strip, Cabinet Trim	28480	5000-0051	1	
5000-0637	Spring, thrust	28480	5000-0637	1	
5000-0732	Rear side cover, 5 x 11 FM	28480	5000-0732	1	
5000-0733	Front side cover, 5 x 11 FM	28480	5000-0733	1	
5020-0348	Shaft	28480	5020-0348	1	
5020-0630	Hub - Dial	28480	5020-0630	1	
5020-0639	Casting - Cap. Drive Assembly	28480	5020-0639	1	
5020-0641	Shaft - Spur Gear	28480	5020-0641	1	
5040-0212	Insulator, flexible, coupler	28480	5040-0212	1	
5040-0234	Pilot Light - Jewel	28480	5040-0234	2	
5040-0235	Pilot Light - Base	28480	5040-0325	2	
5040-0607	Disc. Assembly, Vernier Drive	28480	5040-0607	1	
5040-0642	Indicator - Dial	28480	5040-0619	1	
5040-0631	Bracket - Cap. Mount	28480	5040-0631	1	
5060-0020	Gear, Assembly	28480	5060-0020	1	
5060-0021	Gear, Assembly	28480	5060-0021	1	
5060-0222	Handle Assembly, side	28480	5060-0222	1	
5060-0731	Frame, Assembly, 5 x 11 FM	28480	5060-0731	1	
5060-0739	Top Cover Assembly, 11L FM	28480	5060-0739	1	
5060-0751	Bottom Cover Assembly, 11L FM	28480	5060-0751	1	
5060-0766	Retainer, 5H Handle Assembly	28480	5060-0766	1	
,0-0767	Foot Assembly, FM	28480	5060-0767	1	
8120-0078	Cable Assembly, power, 7.5 ft. long	70903	KH-4147	2	
9100-0294	Transformer	28480	9100-0294	1	
9140-0029	Coil, R.F., 100 MH	99848	3100-15-101	1	
9211-0248	Carton - Corrugated	84324		1	
9223-0040	Foam - Polyethylene	28480	9223-0040	1	
00651-00101	Deck - Main	28480	00651-00101	1	
00651-00102	Plate - Capacitor	28480	00651-00102	1	
00651-00201	Panel - Front	28480	00651-00201	1	
00651-00202	Panel - Rear	28480	00651-00202	1	
00651-01202	Bracket - Switch	28480	00651-01202	1	
00651-04001	Dial	28480	00651-04001	1	
00651-04101	Plate - Cover	28480	00651-04101	1	
00651-61601	Cable Assembly, Output	28480	00651-61601	1	
00651-61602	Cable Assembly, Input	28480	00651-61602	1	
00651-61901	Range Switch Assembly	28480	00651-61901	1	
00651-63402	Attenuator Assembly	28480	00651-63402	1	
00651-66501	P.C. Board, Osc. Ampl.	28480	00651-66501	1	
00651-66502	P.C. Board, Power Supply	28480	00651-66502	1	

\# See introduction to this section



REFERENCE DESIGNATORS

CHASSIS	A1:
C2-C7	C2,3,5,6
DS1	CR1-CR7
F1	Q2,3,5-7
J1	R1-R15
L1-L4	
P1, P2	
Q1,Q2	
R1	
S2,S3	
T1	
W1	

UNASSIGNED: A1C1, A1C4, A1Q1, A1Q4, A1R16

NOTES:

1. RESISTORS IN OHMS, CAPACITORS IN MICROFARADS UNLESS OTHERWISE INDICATED.
2. REFERENCE DESIGNATORS WITHIN ASSEMBLIES ARE ABBREVIATED. ADD ASSEMBLY DESIGNATION AS PREFIX, TO FORM COMPLETE DESIGNATOR.
3. * AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY.
4. ——— INDICATES FEEDBACK.
5. INDICATES ASSEMBLY BOARD.
6. ⏚ = CHASSIS GROUND.
7. ◯ INDICATES FRONT PANEL ADJUST., ⊘ INDICATES SCREWDRIVER ADJUST.

Figure 5-9. Regulated Power Supply Schematic

01761-2

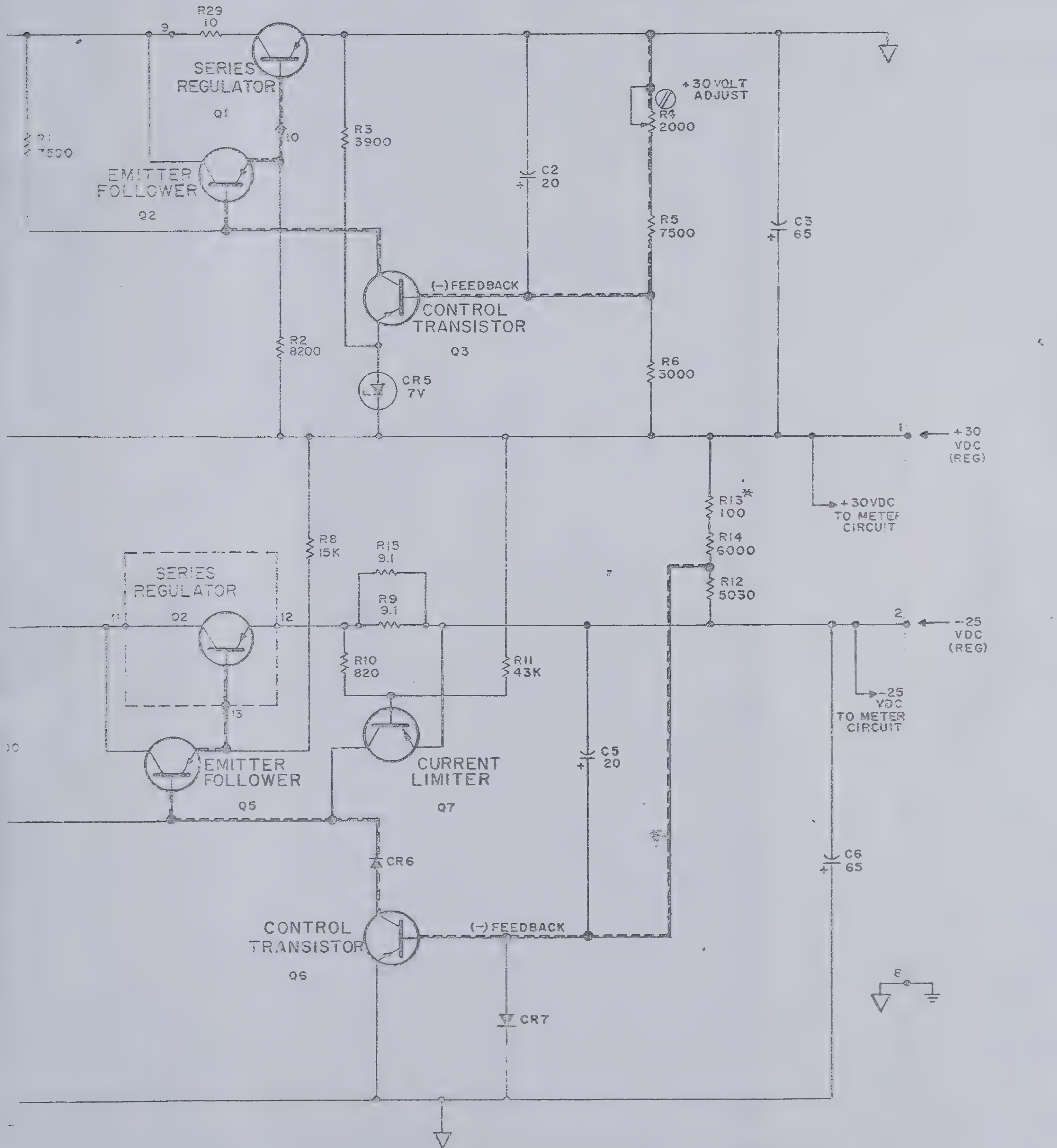


Figure 5-9. Regulated Power Supply Schematic

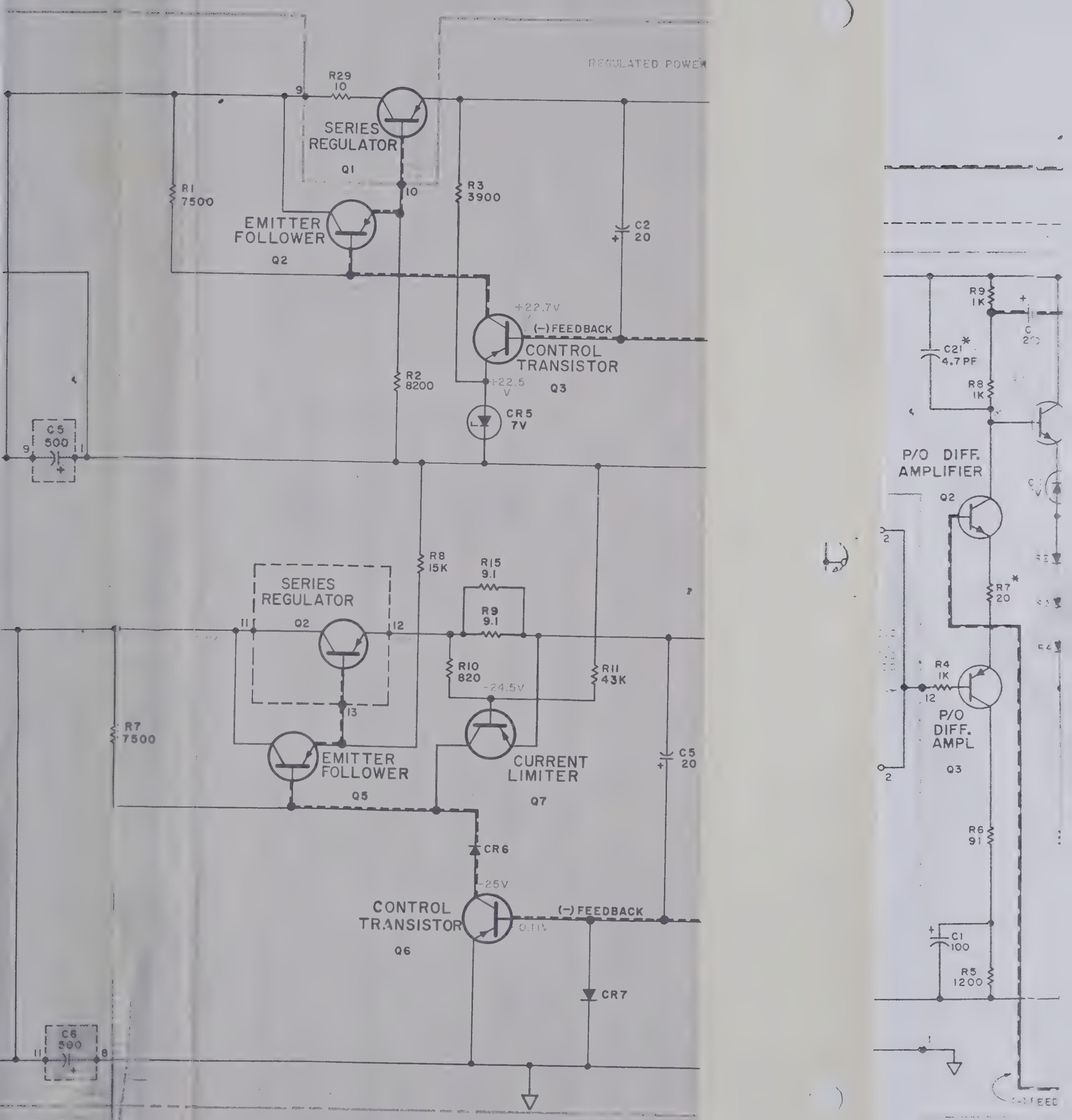
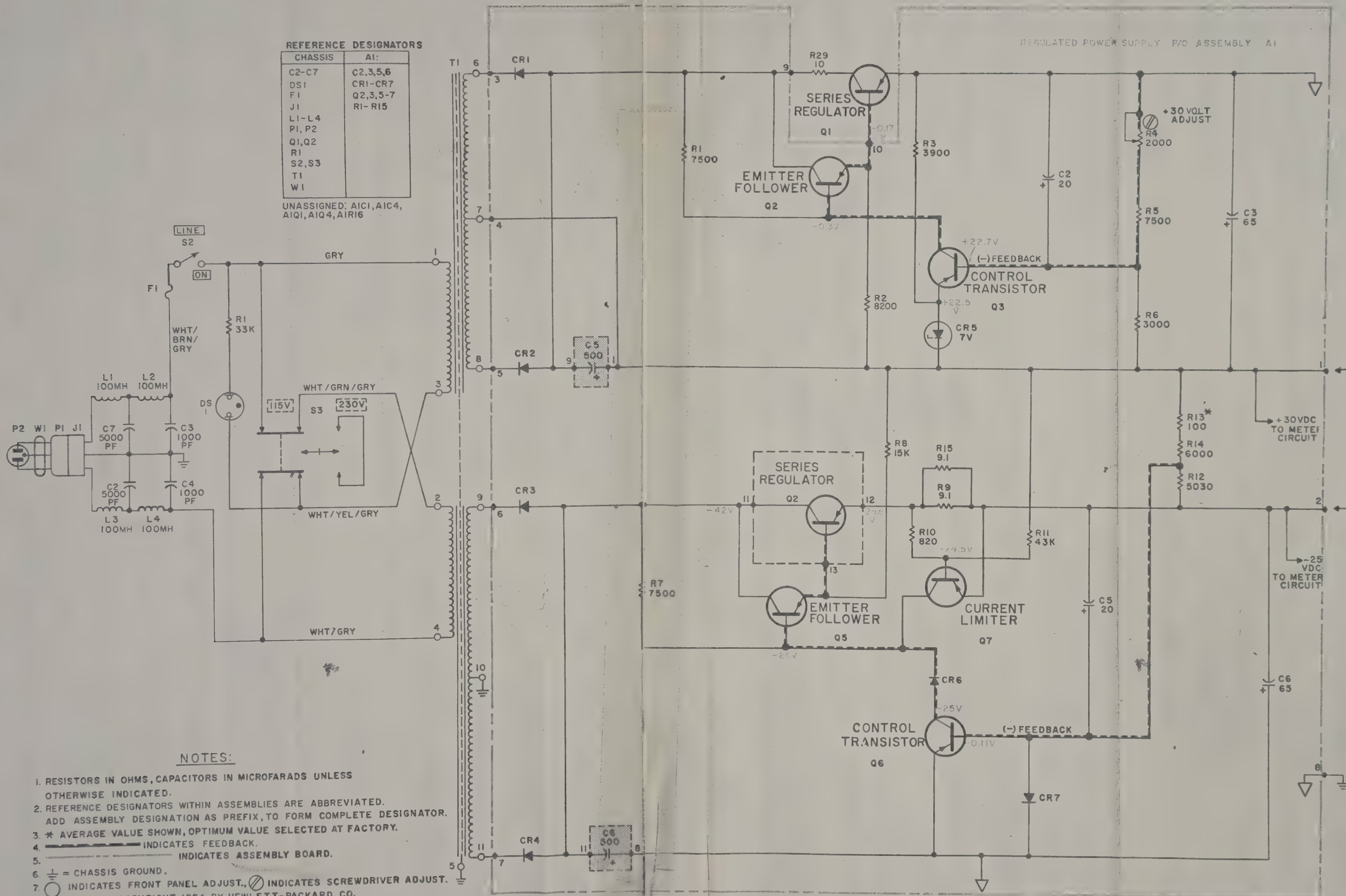


Figure 5-9. Regulated Pov

REFERENCE DESIGNATORS

CHASSIS	A1:
C2-C7	C2,3,5,6
DS1	CR1-CR7
F1	Q2,3,5-7
J1	R1-R15
L1-L4	
P1, P2	
Q1,Q2	
R1	
S2,S3	
T1	
W1	

UNASSIGNED: A1C1, A1C4, A1Q1, A1Q4, A1R16



NOTES:

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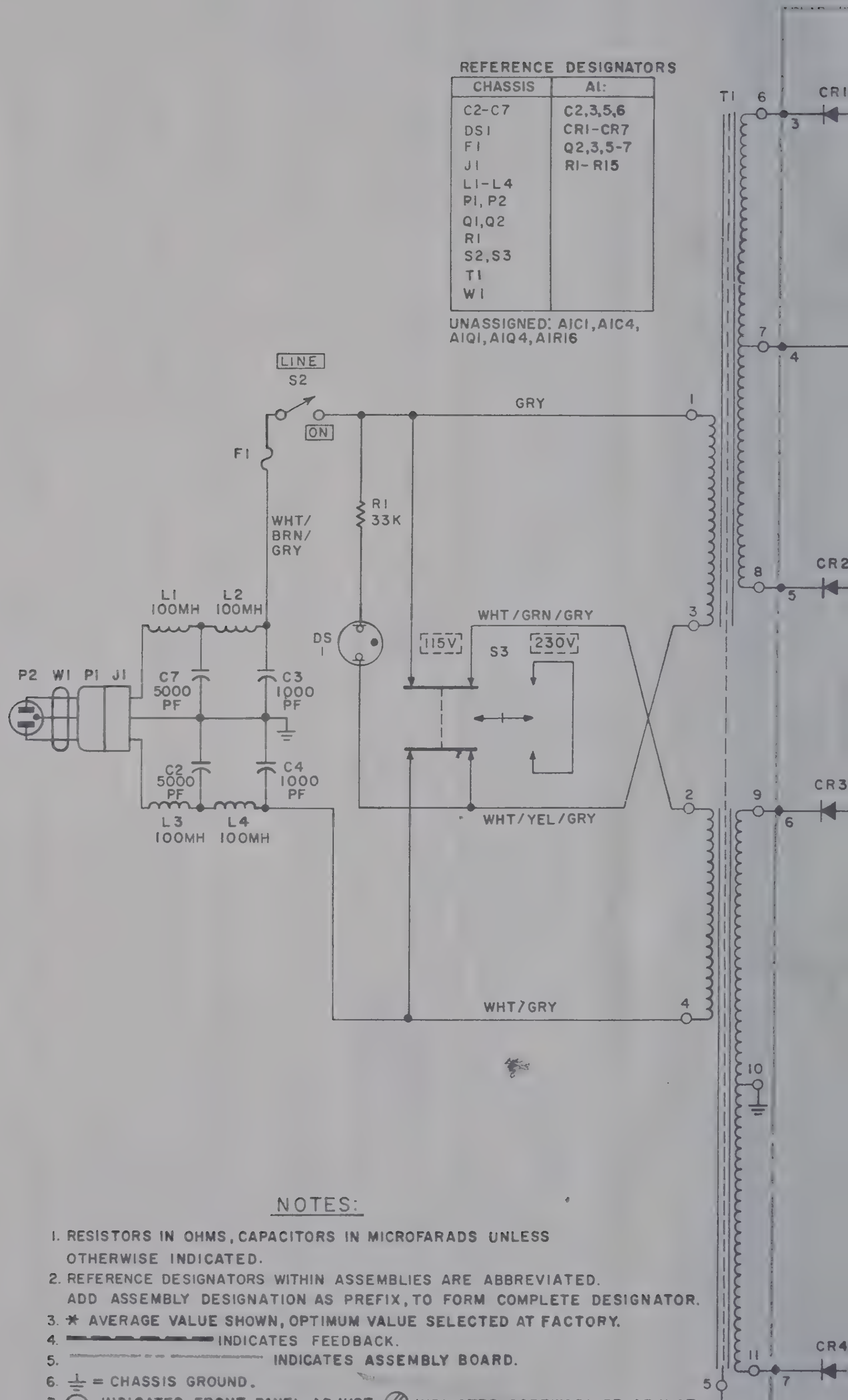
2. REFERENCE DESIGNATORS WITHIN ASSEMBLIES ARE ABBREVIATED. ADD ASSEMBLY DESIGNATION AS PREFIX, TO FORM COMPLETE DESIGNATOR.
3. * AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY.
4. ▬▬▬ INDICATES FEEDBACK.
5. ——— INDICATES ASSEMBLY BOARD.
6. ⏚ = CHASSIS GROUND.
7. ◯ INDICATES FRONT PANEL ADJUST., ⊘ INDICATES SCREWDRIVER ADJUST.

Figure 5-9. Regulated Power Supply Schematic

REFERENCE DESIGNATORS

CHASSIS	A1:
C2-C7	C2,3,5,6
DS1	CR1-CR7
F1	Q2,3,5-7
J1	R1-R15
L1-L4	
P1, P2	
Q1,Q2	
R1	
S2,S3	
T1	
W1	

UNASSIGNED: A1C1,A1C4, A1Q1,A1Q4,A1R16



NOTES:

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2. REFERENCE DESIGNATORS WITHIN ASSEMBLIES ARE ABBREVIATED. ADD ASSEMBLY DESIGNATION AS PREFIX, TO FORM COMPLETE DESIGNATOR.
3. ✱ AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY.
4. ▬▬▬▬ INDICATES FEEDBACK.
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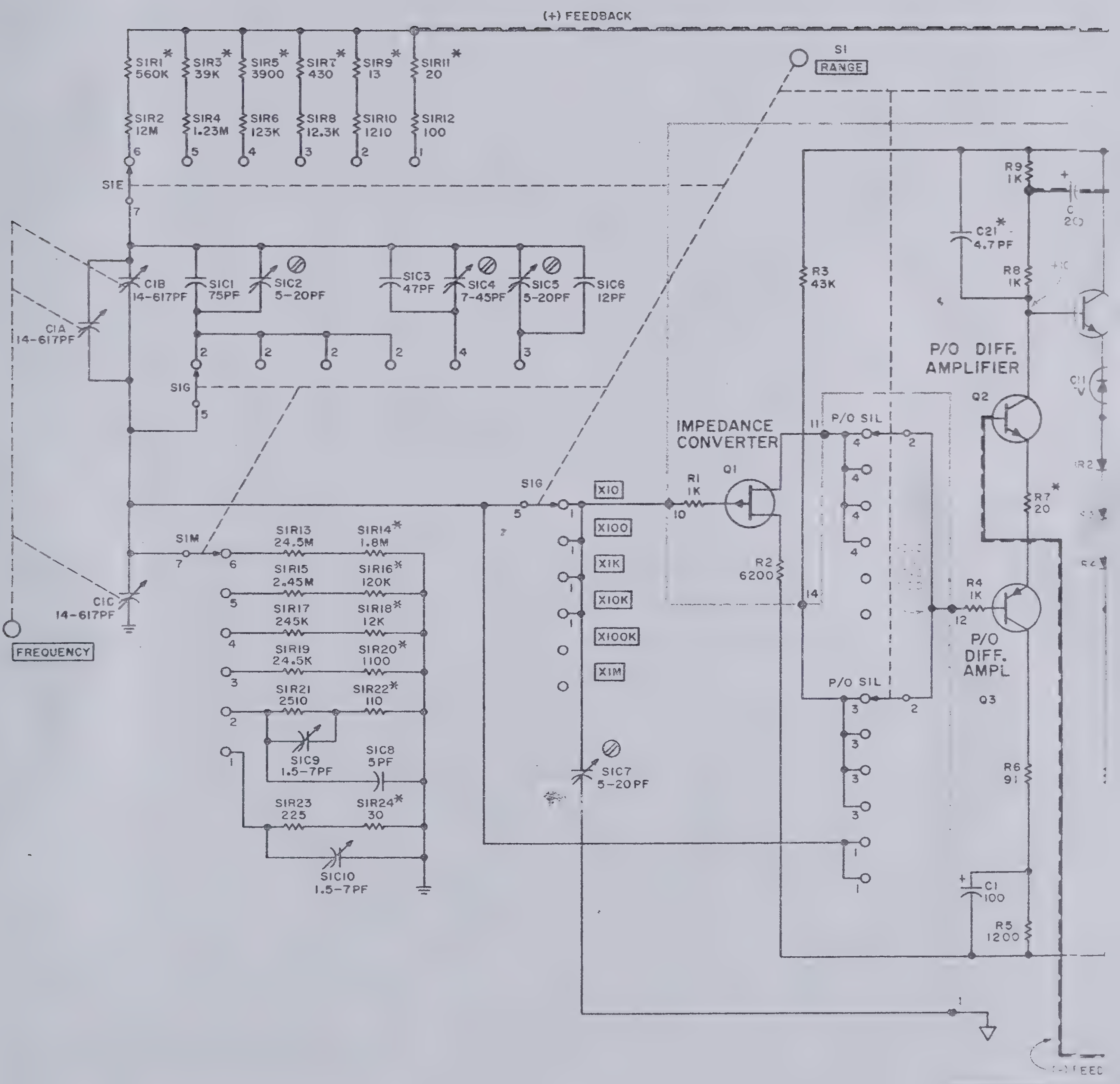
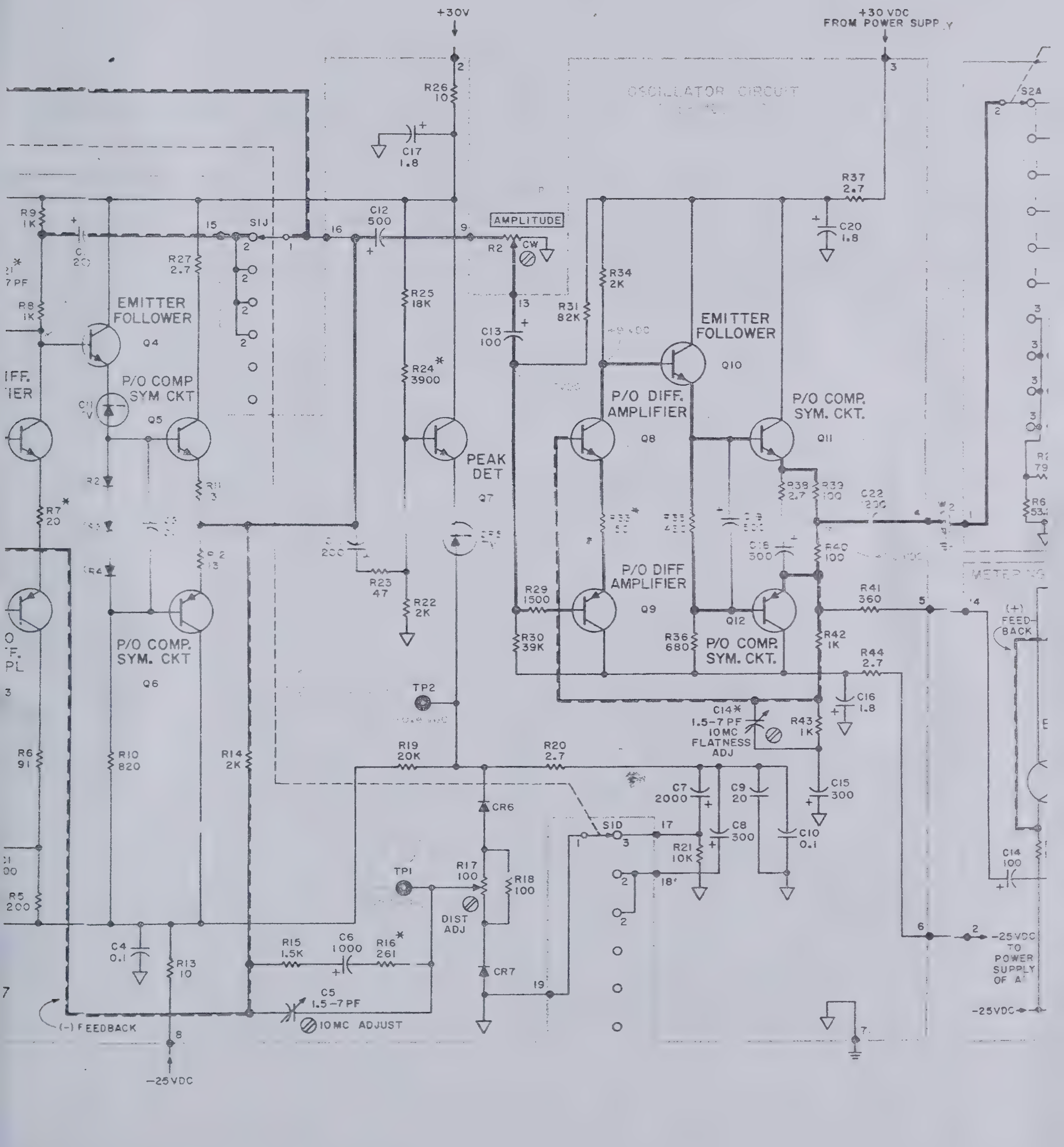
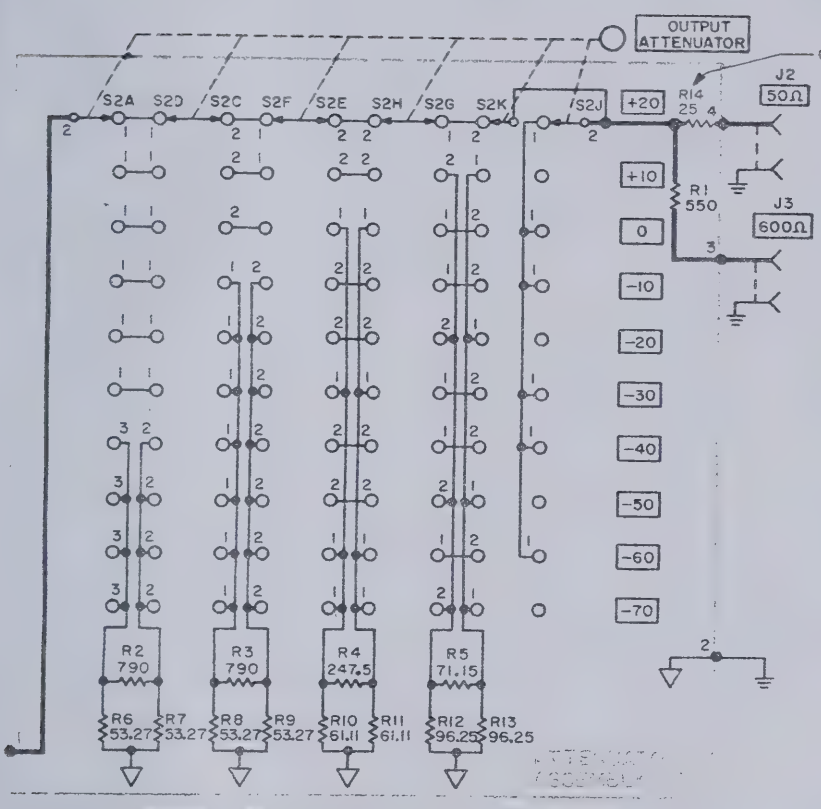
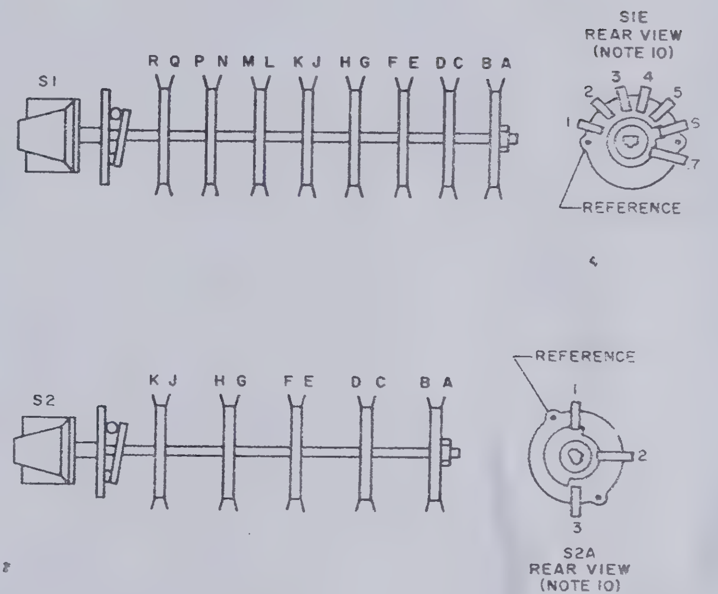
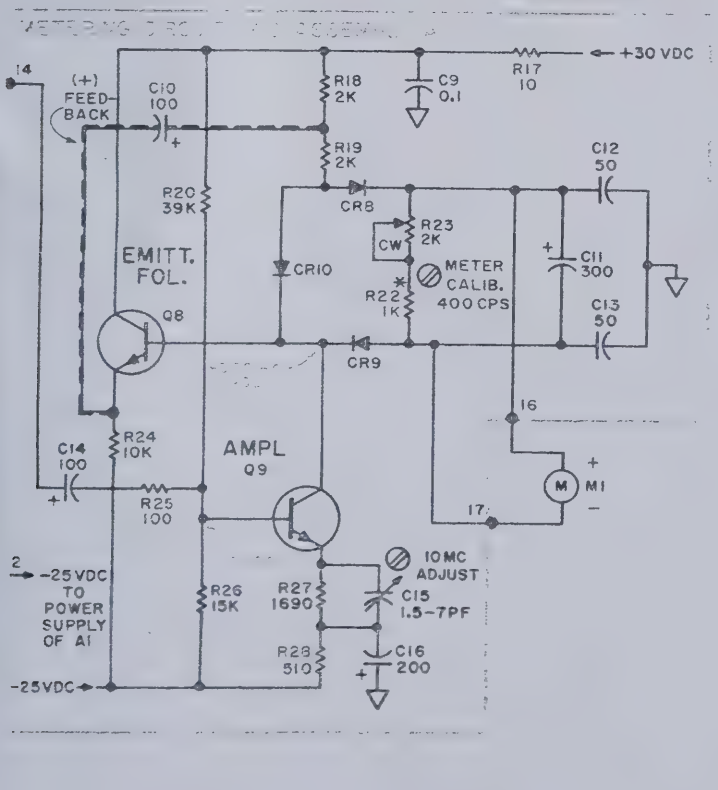

(+) FEEDBACK
S1
RANGE
S1R1* 560K
S1R3* 39K
S1R5* 3900
S1R7* 430
S1R9* 13
S1R11* 20
S1R2 12M
S1R4 1.23M
S1R6 123K
S1R8 12.3K
S1R10 1210
S1R12 100
S1E
C1B 14-617PF
C1A 14-617PF
S1C1 75PF
S1C2 5-20PF
S1C3 47PF
S1C4 7-45PF
S1C5 5-20PF
S1C6 12PF
S1G
S1M
C1C 14-617PF
FREQUENCY
S1R13 24.5M
S1R14* 1.8M
S1R15 2.45M
S1R16* 120K
S1R17 245K
S1R18* 12K
S1R19 24.5K
S1R20* 1100
S1R21 2510
S1R22* 110
S1C9 1.5-7PF
S1C8 5PF
S1R23 225
S1R24* 30
S1C10 1.5-7PF
X10
X100
X1K
X10K
X100K
X1M
S1C7 5-20PF
IMPEDANCE CONVERTER
Q1
R1 1K
R2 6200
R3 43K
P/O S1L
P/O S1L
R9 1K
C21* 4.7 PF
R8 1K
P/O DIFF. AMPLIFIER
Q2
R7* 20
R4 1K
P/O DIFF. AMPL
Q3
R6 91
C1 100
R5 1200



+30V
+30 VDC
FROM POWER SUPPLY
OSCILLATOR CIRCUIT
R26
10
C17
1.8
R37
2.7
C20
1.8
S2A
R9
1K
C12
500
SIJ
AMPLITUDE
R2
CW
R27
2.7
R25
18K
R34
2K
R8
1K
EMITTER
FOLLOWER
Q4
C13
100
R31
82K
EMITTER
FOLLOWER
Q10
R24
3900
P/O COMP
SYM CKT
Q5
P/O DIFF.
AMPLIFIER
Q8
P/O COMP.
SYM. CKT.
Q11
PEAK
DET
Q7
R38
2.7
R39
100
C22
R7
20
R23
47
R22
2K
C18
500
R40
100
R29
1500
P/O DIFF
AMPLIFIER
Q9
R41
360
P/O COMP.
SYM. CKT
Q6
R30
39K
R36
680
Q12
P/O COMP.
SYM. CKT.
R42
1K
(+)
FEED-
BACK
R44
2.7
TP2
C14*
1.5-7 PF
10MC
FLATNESS
ADJ
C16
1.8
R43
1K
R6
91
R10
820
R14
2K
R19
20K
R20
2.7
C7
2000
C9
20
C15
300
CR6
SID
C8
300
C10
0.1
R21
10K
TP1
R17
100
R18
100
DIST
ADJ
C14
100
R5
200
C4
0.1
R13
10
R15
1.5K
C6
1000
R16*
261
CR7
-25VDC
TO
POWER
SUPPLY
(-) FEEDBACK
C5
1.5-7PF
10MC ADJUST
-25VDC
-25VDC







NOTES:

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2. RESISTORS IN OHMS, CAPACITORS IN MICROFARADS UNLESS OTHERWISE INDICATED.
3. ▭ INDICATES FRONT PANEL LOCATION.
4. * AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY.
5. ▬ ▬ ▬ INDICATES FEEDBACK.
6. — — — INDICATES ASSEMBLY BOARD.
7. ⏚ = CHASSIS GROUND.
8. S1 IS SHOWN IN X10 POSITION. S2 IS SHOWN IN +20DBM POSITION.
9. ○ INDICATES FRONT PANEL ADJUST. ⊘ INDICATES SCREWDRIVER ADJUST.
10. WHEN COUNTING CONTACTS ON WAFERS FROM REFERENCE, ONLY FUNCTIONAL CONTACTS ARE COUNTED

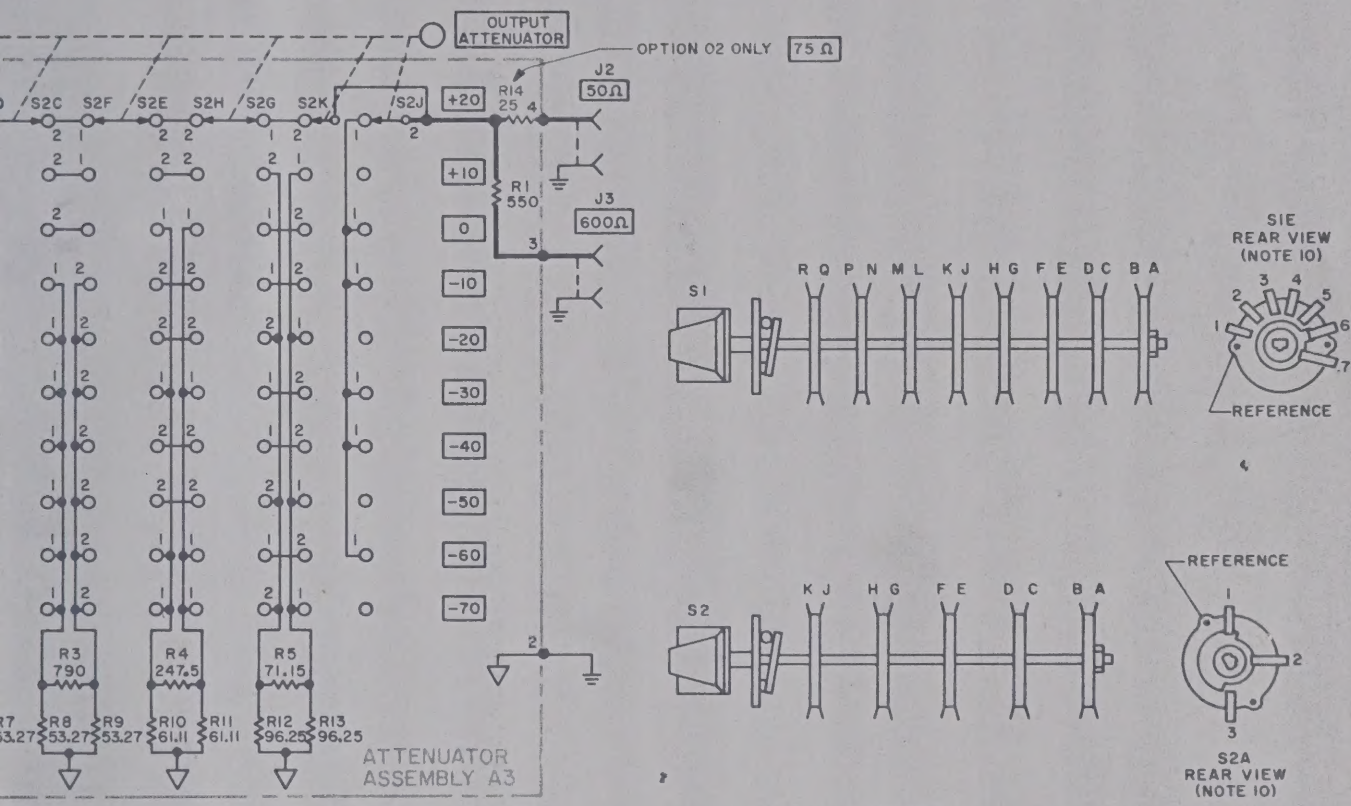
REFERENCE DESIGNATORS

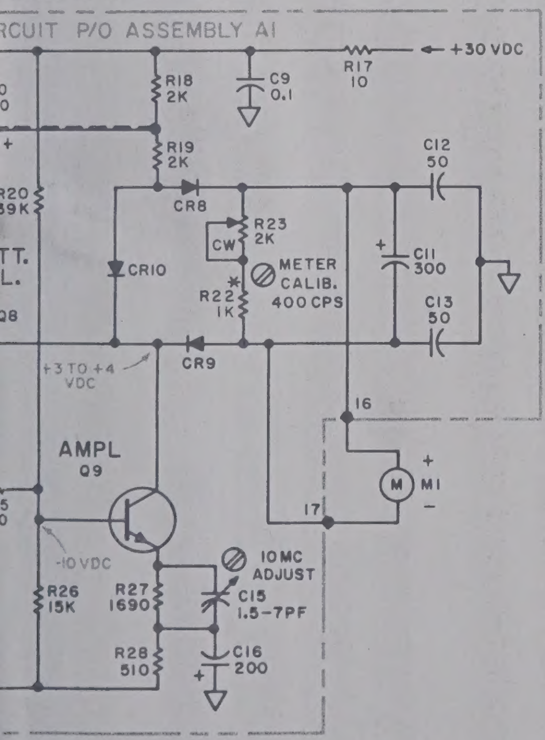
CHASSIS	A1	A2	A3	S1
C1A, B, C J2, J3 M1 W2	C9-C16 CR8-CR10 Q8, Q9 R17-20, 22-28	C1-C22 CR1-CR7 Q1-Q12 R1-27, 29-31, 33-44 TP1, TP2	R1-R13 S2A, C THRU H, J, K	C1-C10 R1-R24 S1D, E, G, J, L, M

NOT ASSIGNED: A1R21, A2R28, A2R32, A3S2B

651A OSC AND METERING CIRCUIT -416C

Figure 5-8. Oscillator Schematic





NOTES:

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2. RESISTORS IN OHMS, CAPACITORS IN MICROFARADS UNLESS OTHERWISE INDICATED.
3. ▭ INDICATES FRONT PANEL LOCATION.
4. * AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY.
5. ▬ ▬ ▬ INDICATES FEEDBACK.
6. — — — INDICATES ASSEMBLY BOARD.
7. ⏚ = CHASSIS GROUND.
8. S1 IS SHOWN IN X10 POSITION. S2 IS SHOWN IN +20DBM POSITION.
9. ◯ INDICATES FRONT PANEL ADJUST. ⊘ INDICATES SCREWDRIVER ADJUST.
10. WHEN COUNTING CONTACTS ON WAFERS FROM REFERENCE, ONLY FUNCTIONAL CONTACTS ARE COUNTED

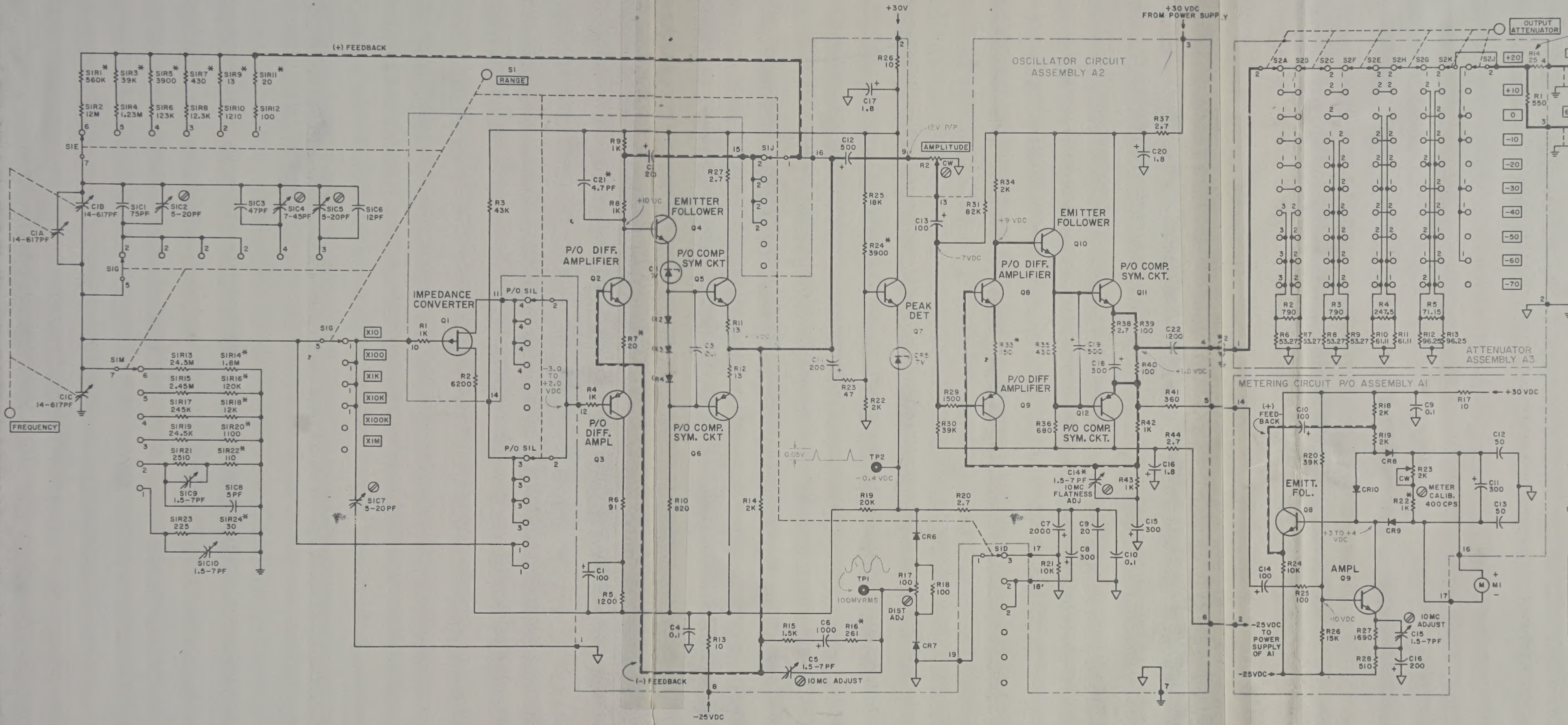
REFERENCE DESIGNATORS

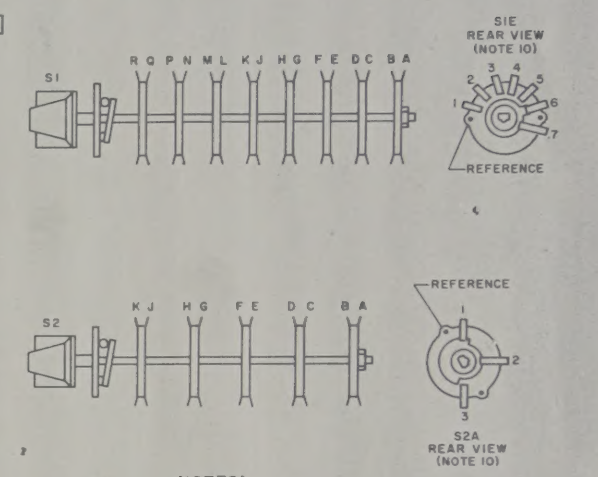
CHASSIS	A1	A2	A3	S1
C1A, B, C J2, J3 M1 W2	C9-C16 CR8-CR10 Q8, Q9 R17-20, 22-28	C1-C22 CR1-CR7 Q1-Q12 R1-27, 29-31, 33-44 TP1, TP2	R1-R13 S2A, C THRU H, J, K	C1-C10 R1-R24 S1D, E, G, J, L, M

NOT ASSIGNED: A1R21, A2R28, A2R32, A3S2B

651A OSC AND METERING CIRCUIT -416C

Figure 5-8. Oscillator Schematic





NOTES:

1. REFERENCE DESIGNATORS WITHIN ASSEMBLIES ARE ABREVIATED. ADD ASSEMBLY DESIGNATION AS PREFIX, TO FORM COMPLETE DESIGNATOR.
2. RESISTORS IN OHMS, CAPACITORS IN MICROFARADS UNLESS OTHERWISE INDICATED.
3. ▭ INDICATES FRONT PANEL LOCATION.
4. * AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY.
5. ▬ ▬ ▬ ▬ INDICATES FEEDBACK.
6. ——— — — ——— INDICATES ASSEMBLY BOARD.
7. ⏚ = CHASSIS GROUND.
8. S1 IS SHOWN IN X10 POSITION. S2 IS SHOWN IN +20DBM POSITION.
9. ◯ INDICATES FRONT PANEL ADJUST. ⊘ INDICATES SCREWDRIVER ADJUST.
10. WHEN COUNTING CONTACTS ON WAFERS FROM REFERENCE, ONLY FUNCTIONAL CONTACTS ARE COUNTED

REFERENCE DESIGNATORS

CHASSIS	A1	A2	A3	S1
C1A, B, C	C9-C16	C1-C22	R1-R13	C1-C10
J2, J3	CR8-CR10	CR1-CR7	S2A, C THRU H, J, K	R1-R24
M1	Q8, Q9	Q1-Q12		S1D, E, G, J, L, M
W2	R17-20, 22-28	R1-27, 29-31, 33-44		
		TP1, TP2		

NOT ASSIGNED: A1R21, A2R28, A2R32, A3S2B

651A OSC AND METERING CIRCUIT -416C

01761-3

Figure 5-8. Oscillator Schematic